Living well with chronic kidney disease: ehealth interventions to support self-management in China

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Citation

Shen, H. (2021, October 14). *Living well with chronic kidney disease: ehealth interventions to support self-management in China*. Retrieved from https://hdl.handle.net/1887/3217039

Living Well with Chronic Kidney Disease:

eHealth Interventions to Support Self-management in China

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Layout & cover design: Hongxia Shen
Print: Printsupport4u
ISBN : 978-94-92597-81-6

Living Well with Chronic Kidney Disease:
eHealth Interventions to Support Self-management in China

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties

te verdedigen op donderdag 14 oktober 2021
klokke 10.00 uur

door

Hongxia Shen
geboren te Yanjin, China
in 1991

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For my family

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Chapter 1

General introduction

General introduction

The burden of chronic kidney disease

Chronic kidney disease (CKD) is a severe public health problem [1, 2]. Globally, around 698 million individuals are affected by CKD [3]. CKD is defined as kidney damage or a measured glomerular filtration rate (GFR) ≤ 60 mL/min/1.73m^2 for more than three months, and is classified into five stages based on the decline in GFR and level of albuminuria [4]. Numerous detrimental health outcomes are linked to CKD including kidney failure, accelerated cardiovascular disease (CVD) and premature death [5-7]. A recent study reported that globally, 1.4 million CVD-related deaths and 25.3 million CVD disability-adjusted life years are attributable to impaired kidney function [8]. Also, living with CKD involves challenges associated with CKD management, including dealing with symptoms and disability; monitoring physical indicators; managing complex medication regimens; maintaining proper levels of nutrition, diet, and exercise; adjusting to the psychological and social demands [9, 10]. After CKD progression, patients with end stage renal disease (ESRD) rely on dialysis treatment or kidney transplantation; those receiving maintenance dialysis suffer from physical and emotional symptoms, exhibit a high prevalence of depression, and experience substantial impairments in quality of life [11]. Additionally, health-related and societal costs of CKD constitute a substantial economic burden [1, 12, 13].

Disease self-management of patients with CKD

The World Kidney Day Steering Committee has declared 2021 as the year of "Living Well with Kidney Disease." Empowering patients in their CKD management may help deal with the involved challenges and minimize the burden and consequences of CKD-related symptoms to enable increased life participation (i.e. the ability to do meaningful activities of life) [14, 15]. Patients' involvement in the management of their own care is referred to as disease self-management (hereafter referred to as 'self-management'), which is defined as "*an individual's ability to manage the symptoms, treatment, physical and psychosocial consequences, and lifestyle changes inherent to the life with a chronic condition*" [16]. As previously noted, self-management is comprised of three main tasks: medical, emotional, and role management. Hence, self-management is not limited to medical management but also aims to optimize the uptake of new meaningful behaviors or life roles and it promotes adequate coping with disease consequences [16]. The benefits of CKD self-management are well documented. Appropriate self-management has the potential to optimize a patient's ability to perform the cognitive, behavioral, and emotional behavior necessary to maintain a satisfactory health-related quality of life [17]. Also, for patients with CKD, interventions supporting self-management can not only improve self-management behaviors [18-20], but also health outcomes and quality of life [21, 22], and may even slow disease progression [23-26]. Hence, optimizing CKD self-management is of utmost importance to reduce disease burden, optimize health outcomes and control health care expenditures [24].

eHealth to support CKD self-management

Electronic health (eHealth) based interventions are being increasingly developed to support CKD self-management. The most cited definition of eHealth is that of Eysenbach [27]: "*e-health is an emerging field in the intersection of medical informatics, public health and business, referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, the term characterizes not only a technical development, but also a state-of-mind, a way of thinking, an attitude, and a commitment for networked, global thinking, to improve health care locally, regionally, and worldwide by using information and communication technology.*" eHealth can be operationalized into three types following previous categorizations [28, 29]. The first is 'inform, monitor and track', encompassing the use of eHealth technologies to observe and study health parameters. The second type is 'interaction', covering the use of eHealth to facilitate communication between all users. The final type of eHealth is 'data utilization', referring to the collection, management, and use of health and medical data sources to inform decision making and intervention development. eHealth can help patients to achieve personal health goals, and make patients feel more responsible for their own health status [30]. Moreover, eHealth can facilitate remote patient communication and exchange of (health) data. In this way, eHealth can help to increase health care efficiency while maintaining a wide-scale, cost-effective health care approach [31]. Previous evidence suggests that eHealth self-management interventions have the potential to improve healthy behaviors and health outcomes of patients with CKD [32-36], and are found to be feasible and acceptable for patients with CKD and healthcare professionals (HCPs) [35].

Translation of effective CKD self-management eHealth intervention to Chinese settings

However, research on CKD self-management eHealth interventions has mostly focused on high-income countries, whereas CKD burden is highest in low- and middle-income countries (LMICs) [37]. A systematic review reported that 388 million adults had CKD in LMICs [37]. The burden of CKD is particularly high in China, with the highest number of patients being affected by CKD (132 million) [3]. Around one fifth of the global burden of CKD is in China [3, 38]. Patients and HCPs face challenges in the accessibility of CKD care due to the lack of a strong primary care system in China. For instance, in rural China, the long distance to healthcare facilities is a significant problem for patients with CKD. eHealth interventions provide great potential to address these challenges such as so-called ‘internet hospitals’ allowing patients to receive high-quality care from a top-tier hospital from either their own home or a local clinic, through a video or telephone connection [39]. Hence, eHealth self-management interventions have a great potential to decrease the burden of CKD in countries with fewer resources, including in China.

One possible solution to decrease the burden of CKD is to translate CKD self-management eHealth interventions proven effective in high resource settings to low resource settings. An example of an extensively studied and effective CKD self-management eHealth intervention is ‘Medical Dashboard (MD)’ [40-42]. The MD, developed in the Netherlands, enables patients and HCPs to monitor and track healthy behaviors and disease parameters. It was used in the Outpatient Clinic Kidney Transplant of the Leiden University Medical Center since February 2016. In a randomized controlled trial (RCT), the use of MD has been shown to improve patients’ adherence to sodium restriction intake and blood pressure control [40, 42]. Also, patients reported being highly satisfied with the online disease management system used on the platform [41]. Our research team is closely working with its developers to amend and upscale the intervention to Chinese settings. All core intervention components of MD are presented in Textbox 1 and Figure 1.

Textbox 1. Core intervention components and functionalities of Medical Dashboard.

- **Motivational interviewing:** Patients are provided with a one-hour individual motivational interview, which focuses on discussing barriers, benefits, and strategies for self-management; setting personal goals, and strengthening intrinsic motivation and self-efficacy.
- **Education:** Patients are provided with education, a kidney-friendly cookbook, instructions for self-monitoring blood pressure (using a Microlife Watch blood pressure home device), dietary intake (using an online food diary) and 24-hour urinary sodium excretion (using an innovative point-of-care chip device).
- **Self-monitoring**: Patients are instructed to take health measurements at home (e.g. blood pressure, weight and glucose) and enter the results of these measurements via the secure “self-care” website www.bonstat.nl. The measurements entered via this website are linked real-time to the Medical Dashboard interface.
- **Combination of home and hospital measurements in the Medical Dashboard**: The measurements that patients take at home and the measurements performed during hospital visits are visualized jointly in the Medical Dashboard.
- **Online information support**: Patients are provided with online disease-related information, tips and suggestions focusing not only on medical knowledge, but also on how to obtain and sustain social support, refusal skills, medication adherence strategies, physical exercise, healthy eating, smoking cessation and reduced alcohol intake.
- **Personal coaching**: Patients are coupled with one of four personal coaches: three health psychologists and one dietician. Following the self-monitoring measurements, patients are provided with feedback by telephone from their coach or during hospital visits. The discussion focuses on the progression, achievements, barriers and possible solutions of self-management.

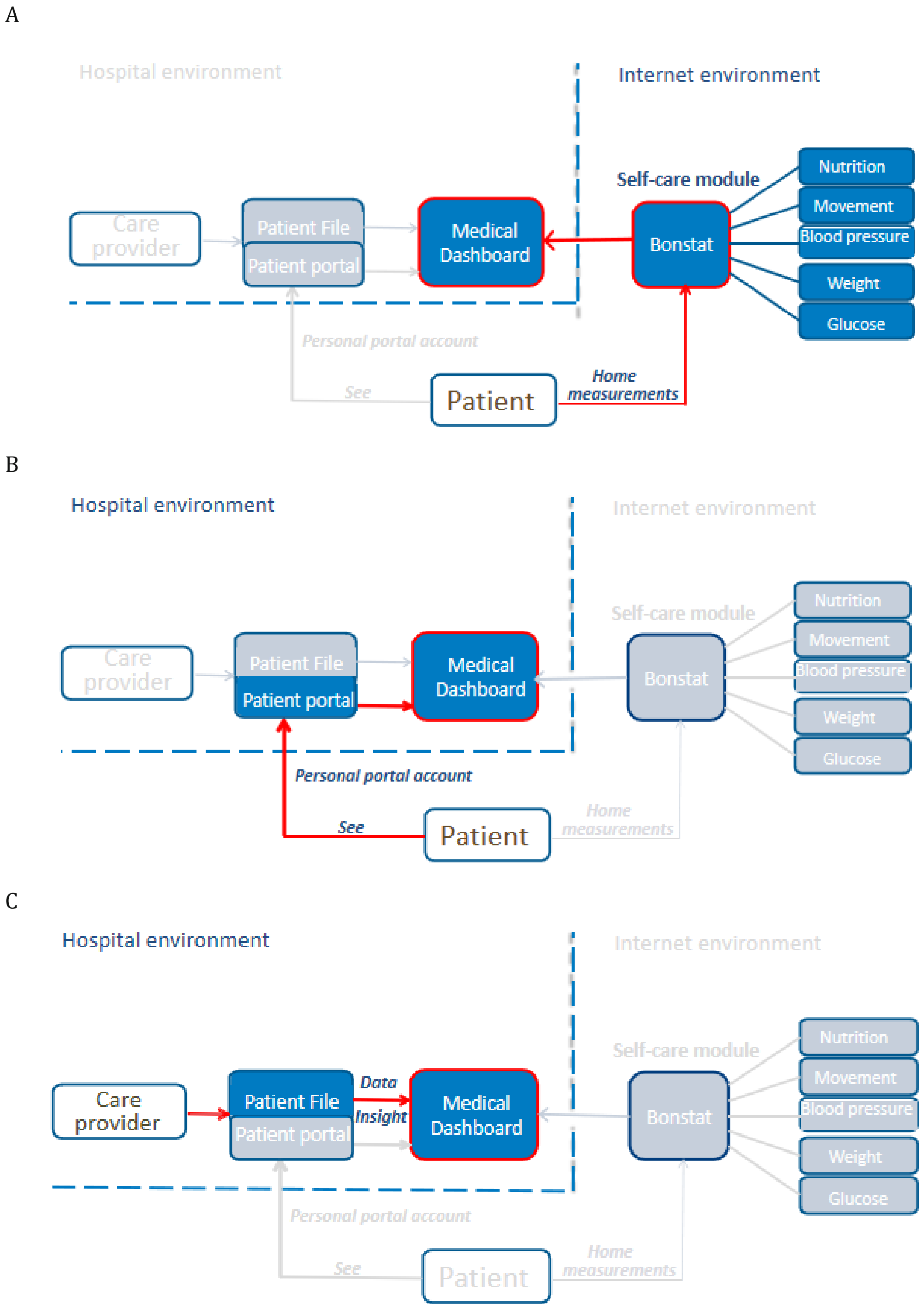

Figure 1. Medical Dashboard. (A) self-monitoring; (B, C) combination of home and hospital measurements in the Medical Dashboard, online information support.

Knowledge to inform CKD self-management eHealth intervention in Chinese settings

As self-management occurs in a social context [43], applying a 'one-size-fits-all' approach and simply translating the intervention as a whole to a different context is not sufficient. Based on the SETTING-tool used for mapping local contexts for (lung) health interventions in diverse low-resource settings [44], key contextual elements including local beliefs (i.e. an idea or principle judged to be true), perceptions (i.e. the organized cognitive representations that individuals have about a subject), attitudes (i.e. an individual's overall evaluation of a subject based on certain perceptions) and needs (i.e. demands and requirements that people require to address their problems) of the target population towards CKD self-management eHealth intervention should be assessed and integrated into implementation strategies of CKD self-management eHealth intervention in China [44, 45]. Also, the prevalence of CKD and which group of people are at high risk of having CKD in real settings need to be examined. However, as of yet, this knowledge about local contexts for CKD self-management eHealth intervention in China is not available.

Aim of this thesis

To overall aim of this thesis is to inform the adaptation and evaluation of a tailored CKD self-management eHealth intervention in China based on the Dutch MD intervention. **Chapter 2** provides an overview of the literature regarding the implementation and effectiveness of eHealth self-management interventions for patients with CKD. **Chapter 3** describes the extent of the burden of CKD in Chinese settings assessed by a repeated cross-sectional study; it shows the prevalence of reduced kidney function, kidney function decline and related risk factors in a Chinese primary care population. **Chapter 4** presents the research methods used to develop and tailor a MD intervention for Chinese settings by using the Intervention Mapping approach. **Chapter 5** examines the beliefs, perceptions and needs of Chinese patients with CKD and HCPs towards CKD self-management. **Chapter 6** presents the perceptions, attitudes and needs of Chinese patients with CKD and HCPs towards eHealth/digital tools to support CKD self-management. Finally, I discuss the major findings described in Chapters 2-6 and their implications for development and implementation of CKD self-management eHealth intervention in China and for future research.

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Chapter 2

Electronic health self-management interventions for patients with chronic kidney disease: systematic review of quantitative and qualitative evidence

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Journal of Medical Internet Research 2019;21(11): e12384

Abstract

Background

Chronic kidney disease (CKD) poses a major challenge to public health. In CKD patients, adequate disease self-management has been shown to improve both proximal and distal outcomes. Currently, electronic health (eHealth) interventions are increasingly used to optimize patients' self-management skills. This study aimed to systematically review the existing evidence regarding the implementation and effectiveness of eHealth self-management interventions for patients with CKD.

Methods

Following a search in 8 databases (up to November 2017), quantitative and qualitative data on process and effect outcomes were extracted from relevant studies. Quality was appraised using the Crowe Critical Appraisal Tool; narrative synthesis was performed to analyze the data extracted.

Results

Of the 3307 articles retrieved, 24 (comprising 23 studies) were included in this review; of these, almost half were appraised to be of low to moderate quality. There was considerable heterogeneity in the types of interventions used and the outcomes measured. A total of 10 effect and 9 process outcome indicators were identified. The most frequently reported effect outcome indicators were specific laboratory tests and blood pressure, whereas satisfaction was the most frequently reported process outcome indicator. Positive effects were found for proximal outcomes, and mixed effects were found for more distal outcomes. High feasibility, usability, and acceptability of and satisfaction with eHealth self-management interventions were reported. The determinant *ability of health care professionals to monitor and, if necessary, anticipate on patient measurements online* was mostly cited to influence patients' adherence to interventions.

Conclusions

eHealth self-management interventions have the potential to improve disease management and health outcomes. To broaden the evidence base and facilitate intervention upscaling, more detailed descriptions and thorough analysis of the intervention components used are required. In addition, we advise future researchers to carefully consider their choice of outcomes based on their sensitivity for change. In this way, we ensure that relevant effects are captured and legitimate conclusions are drawn.

INTRODUCTION

Chronic kidney disease (CKD) is a major public health concern [1-3]. Globally, more than 697 million individuals are affected by CKD [4]. CKD is defined as kidney damage or a measured glomerular filtration rate (GFR) of ≤60 mL/min/1.73m^2 for more than 3 months. CKD is classified into 5 stages based on GFR decline [5]. The level of kidney function deterioration has a direct relationship with an increase in morbidity and mortality [6], poorer patient outcomes [3], higher hospitalization rates [7], and substantial increase in health care expenditures [8]. Patients with CKD report a lower quality of life (QoL) [9] and may experience severe medical complications and cognitive dysfunction [10].

Disease self-management (hereafter referred to as *self-management*) is defined as “an individual’s ability to manage the symptoms, treatment, physical and psychosocial consequences, and lifestyle changes inherent to the life with a chronic condition” [11]. Adequate self-management is reported to improve patients’ health behaviors targeted by the intervention (i.e. proximal outcomes) and also indirect outcomes, such as disease characteristics and progress (i.e. distal outcomes) [12-14]. Although the potential benefits of self-management interventions are widely reported in the literature, extrapolating these results in day-to-day practice is difficult. Lack of efficacy in practice might be related to a suboptimal implementation of the self-management interventions [15, 16]. Reported barriers were often related to intervention characteristics, such as lack of tailoring to the individual patient. Moreover, a lack of patient involvement in intervention design and insufficient care continuity and accessibility were reported to hamper implementations [17, 18].

Electronic health (eHealth) technologies can help address implementation barriers by making interventions more accessible, acceptable, tailored, and interactive [19-21]. The most cited definition of eHealth is that by Eysenbach [22]:

> *e-health is [...] referring to health services and information delivered or enhanced through the Internet and related technologies. In a broader sense, characterizes [...] to improve health care locally, regionally, and worldwide by using information and communication technology*.

eHealth can help patients achieve personal health goals, and it allows them to feel more responsible for their health status [23]. Moreover, eHealth facilitates remote patient communication and exchange of health data, helping to increase health care efficiency while maintaining a wide-scale, cost-effective health care approach [24]. eHealth interventions have been successfully implemented to support weight loss [25, 26], promote smoking cessation [27], reduce depressive symptoms [28], and decrease mortality rates and acute admissions [29]. In addition, eHealth-based interventions have been successfully applied to manage chronic disease [30-32].

Several studies have reported the use of eHealth-based self-management interventions in CKD [33-36]. Moreover, 3 systematic reviews were published on this topic [37-39]. However, these reviews only concentrated on 1 particular eHealth application, such as telemedicine; dietary mobile apps; and automated information technology tools. Moreover, these reviews focused on a limited number of study designs and outcomes. For example, 2 reviews only included randomized controlled trials (RCTs) [38, 39], and 1 review excluded studies focusing on implementation outcomes such as feasibility, validity, and acceptability [39]. Moreover, none of these reviews [37-39] reviewed the contribution of individual intervention components (e.g. self-monitoring) to the effects found. These limitations of previous reviews make it difficult for researchers and intervention developers to determine which components should be employed to maximize the effectivity of eHealth self-management interventions for CKD patients.

This study, therefore, aimed to systematically review the available evidence on eHealth-based self-management interventions for CKD. In specific, we aimed to review the following: (1) study characteristics and type of eHealth applications used; (2) intervention components implemented and, if possible, their relative contribution to the effect found; (3) both process and effect outcomes; and (4) determinants of implementation.

METHODS

Protocol and Registration

This review was performed according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement [40]. The protocol was registered in the international Prospective Register of Systematic Reviews database (Centre for Reviews and Dissemination [CRD] number: CRD 420 180 81681).

Search Methodology

A systematic search was conducted to identify relevant articles; the search strategy was developed in collaboration with a certified librarian. In total, 8 electronic databases (PubMed, EMBASE, Web of Science, Cochrane Library, EmCare, PsycINFO, Academic

Search Premier, and Science Direct) were searched in November 2017. Search terms covered 3 areas: (1) CKD, (2) eHealth, and (3) self-management (see Additional file 1: https://www.jmir.org/2019/ 11/e12384/) . Reference lists of the included studies were searched to identify other relevant articles. EndNote X9 (Clarivate Analytics) was used to support the review process.

Eligibility Criteria

Inclusion and exclusion criteria (Textbox 1) were determined using the Patients, Interventions, Comparison, Outcomes, Study design methodology [41].

Textbox 1. Inclusion and exclusion criteria for this study.

Inclusion criteria

- Participants—patients classified with chronic kidney disease (stage 1-5).
- Intervention—eHealth technologies ("any information and communication technology designed to deliver or enhance health services and information") applied to facilitate chronic kidney disease patients' self-management ("the care taken by individuals towards their own health and well-being: it comprises the actions they take to lead a healthy lifestyle; to meet their social, emotional and psychological needs; to care for their long-term condition, and to prevent further illness or accidents") [11].
- Comparison—no restrictions.
- Outcomes—articles reporting on clinical (i.e. patients' intermediate outcomes or clinical parameters of disease severity, such as blood pressure, fluid management, and mortality), humanistic (i.e. consequences of disease or treatment on patients' functional status or quality of life, such as physical functioning, well-being, and levels of depression or anxiety), economic and utilization (i.e. measures of health resource utilization, medical costs, and cost-effectiveness), and/or process (i.e. indicators that affect patient care by improving health care delivery or patient-health care interactions and self-management related–factors, such as adherence to intervention, usability of eHealth technologies, and self-efficacy) outcomes.
- Language restrictions—articles needed to be written in English.
- Study design—randomized and nonrandomized controlled trials, noncomparative trials, and qualitative or mixed methods articles.

Exclusion criteria

- Type of electronic health used—studies with devices only used for communication (e.g. a telephone only used for a follow-up call) or data collection (e.g. an internet system solely used to collect patient data without further intervention) purposes.
- Study design—case reports containing ≤3 participants, commentaries, reviews, letters, dissertations, editorials, conference proceeding, and books.

Study Identification

After removal of duplications, titles and abstracts of the retrieved articles were screened independently by 2 reviewers (HS and XC). Articles that did not meet inclusion criteria were removed. Potentially relevant articles were obtained in full text and reviewed independently by 2 authors (HS and XC). Any disagreements between the 2 authors were resolved by consensus or consultation with a third author (RK).

Data Collection

Data collection was performed independently by 2 reviewers (HS and XC) using a standardized data extraction form. Study characteristics, descriptions of eHealth self-management interventions (e.g. intervention components), process and effect outcome indicators, and determinants of implementation were extracted. Discrepancies in extraction were discussed until consensus was reached.

Quality Assessment

Article quality was appraised independently by HS and XC using the Crowe Critical Appraisal Tool (CCAT) [42]—a reliable, widely used quality appraisal tool [43, 44]. Use of the CCAT user guide promoted validity and inter-rater reliability [43-46]. The CCAT form is divided into 8 categories and 22 items, with a total of 99 subitems. Subitems are rated on a scale of *present*, *absent*, or *not applicable*. A 6-point scale ranging from 0 (the lowest) to 5 (the highest) is used to assign score per category, with 40 being the maximum achievable total score.

The CCAT does not allow for a qualitative comparison of appraisal scores. Hence, we used the star score system developed by our research group to compare study quality [47]. First, we calculated a quality score based on the CCAT. Then, a mean score and standard deviation of the quality scores were calculated. Star scores were then assigned to each article: 1 star if a quality score was more than 1 SD below mean; 2 stars if a quality score ranged from 1 SD below mean to mean score, etc. The kappa between the 2 reviewers' scores of quality assessment was 0.63, reflecting substantial agreement [48].

Data Synthesis

Data were reviewed using narrative synthesis [49]. Study characteristics were reviewed, summarized, and analyzed in a spreadsheet. In accordance with previous categorizations of eHealth [32, 39, 50], eHealth self-management interventions were split into 5 major types (see Additional file 2: https://www.jmir.org/2019/11/e12384/). eHealth functionalities used were described based on the technology functionality framework [51, 52]. In addition, based on the operationalization by Mohr et al [53], eHealth-based self-management interventions included were further detailed: (1) intervention components (based on Morrison et al [54]; see Additional file 3: https://www.jmir.org/2019/11/e12384/)—active intervention parts that support self-management behavior, including elements defined as *what* is provided to the user (e.g. education materials, integrated alerts, and video conferencing options), *how* these elements are delivered (e.g. plans and quizzes), and the subsequent intervention workflow defined as *when* they are delivered (e.g. daily use)—and (2) intervention strategies—behavior change techniques [55] that underlie the intervention components (e.g. *role modeling* if the Web-based education materials used include a video of patient who successfully manages his/her disease).

Outcome indicators were classified into 2 categories: effect outcome indicators and process outcome indicators [56]. Effect outcome indicators were outcomes related to self-management, health status, or cost-effectiveness, whereas process outcome indicators were outcomes on care process, health care delivery, or patient-health care interactions (e.g. adherence and usability).

To allow for comparability, we classified the results reported as *positive effect*, *no statistically significant effect*, or *mixed effect* (see Textbox 2). No negative outcomes were reported in the studies included in this review. Only quantitative methods were used to measure effect outcome indicators, whereas mixed methods were used to measure some process outcome indicators. Hence, the classification of the results of the process outcome indicators slightly differs from that of the effect outcome indicators. Outcomes related to patients and care providers are reported separately.

Textbox 2. Outcome indicators for electronic health self-management interventions.

- Effect outcome indicators
  - *Positive effect*—if, after statistical analysis, a significant effect was reported.
  - *No statistically significant effect*—if, after statistical analysis, a nonstatistically significant effect was reported or if no statistical analysis was performed.
  - *Mixed effect*—if results that could be classified as both positive and no effect were reported.
- Process outcome indicators
  - *Positive effect*—if, after statistical analysis, a statistically significant effect was reported or if a positive effect or an improvement between certain points in time was reported (e.g. interviews revealed that patients were highly satisfied with the electronic health application).
  - *No statistically significant effect*—if, after statistical analysis, a nonsignificant effect was reported or if a no effect or no differences between certain points in time was reported.
  - *Mixed effect*—if results that could be classified as both positive and no effect were reported.

The determinants of implementation of eHealth self-management interventions extracted were categorized following the widely cited framework by Fleuren et al [57]. This framework identifies 50 determinants of program implementation in 5 subgroups: (1) characteristics of the sociopolitical context, such as legislation; (2) characteristics of the organization, such as staff turnover; (3) characteristics of the person adopting the innovations (user of the innovation), such as knowledge; (4) characteristics of the innovation, such as complexity; and (5) innovation strategies, such as a training. For example, the study by McGillicuddy et al [36] included in our review mentioned that "six subjects did not complete the lead-in phase, 5 for technical reasons relating to poor internet at their home." This barrier was then mirrored to the 50 determinants in Fleuren framework and classified as a determinant related to the *innovation* and, more specifically, added to the determinant category *perceived quality of eHealth intervention is excellent*. In addition, in each subgroup, we identified the influence of the patients or care providers.

RESULTS

Study Selection

Our search retrieved 3307 articles in total. After removing 1497 duplicates, 1810 relevant articles were screened based on title and abstract. A total of 123 potentially relevant articles were screened full text. Of these papers, 2 described results of the same RCT [58, 59] and were assessed jointly. Finally, 24 articles (comprising 23 studies) [33-36, 58-77] were found eligible for inclusion in this review (Figure 1).

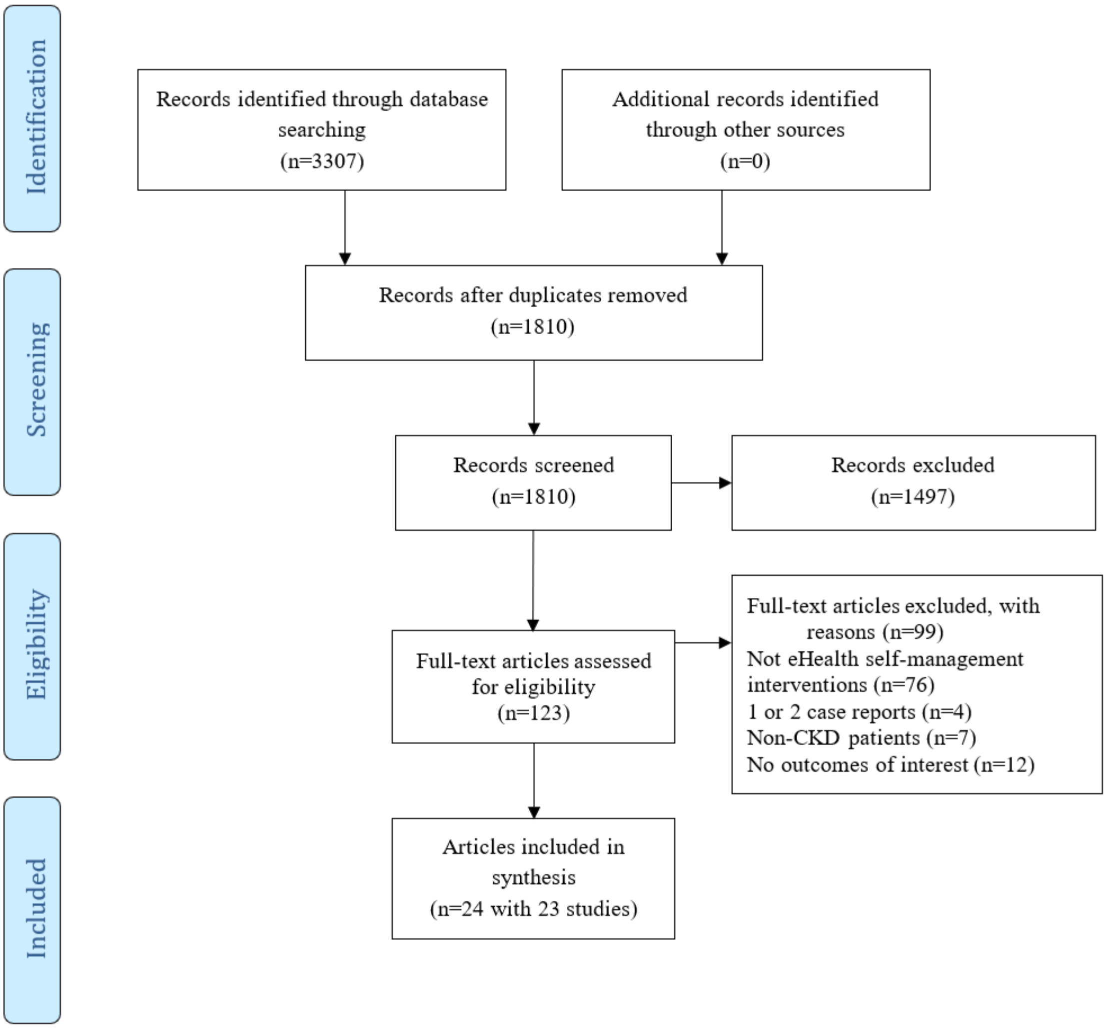

Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart of the systematic review. CKD: Chronic kidney disease; eHealth: electronic health.

Study Characteristics

All 23 studies were published between 2005 and 2017, with 19 of them being conducted between 2012 and 2017 [33-36,58,64-77]. A total of 13 studies were conducted in the United States [33-36,58,60,62-65,69,71,72], followed by 2 studies in the United Kingdom [70, 74]. The research designs used varied; the majority used an RCT design [33-36, 58, 63, 64, 66, 70]. Most studies focused on the usability, acceptability, and feasibility of eHealth self-management interventions [36, 58, 61, 64, 65, 67, 69, 71, 72, 74-77]. Most participants are patients receiving hemodialysis [58, 60, 62-64, 66, 68, 69, 76, 77]. Sample size at baseline ranged from 5 [67] to 601 [34]. Target population age ranged from 21 to 93 years. Intervention duration ranged from 2 weeks [76] to 24 months [61]; 2 studies did not specify intervention duration [58, 67]. A total of 10 studies performed a follow-up measurement [33, 34, 63, 65, 66, 69-71, 73,76]. Moreover, 12 studies included a control group, and 9 of those studies [33, 34, 36, 58, 61, 66, 68, 70, 76] reported *usual care* or no internet-delivered intervention as control condition. The study characteristics have been presented in Additional file 4 (https://www.jmir.org/2019/11/ e12384/).

Quality Appraisal Scores of Studies

Quality of the included articles varied (Table 1). A total of 3 articles [70, 73, 75] were awarded a 4-star rating, 11 [33-36, 59, 63, 65, 66, 69, 74, 76] a 3-star rating, and 10 [58, 60-62, 64, 67, 68, 71, 72, 77] a 2-star rating or lower. Articles with a 4-star rating scored higher on design, sampling, data collection, and ethics compared with those with a 3-star rating or lower. Moreover, 20 articles [34-36, 59-70, 72, 73, 75-77] provided insufficient details on their study design or rationale. Sampling method used (e.g. randomly and purposively) was not reported in 10 articles [35, 60, 62, 65, 67, 71, 73, 74, 76, 77].

Description of Electronic Health Self-Management Interventions

Major types of eHealth, functionalities, and key intervention components used are summarized in Tables 2 and 3. Most eHealth interventions evaluated included *multiple components* (multiple eHealth types) to improve patients' self-management (8/23 articles). Studies included did not provide detail on the specific intervention strategies underpinning these components, such as behavior change techniques. The most frequently used intervention component was self-monitoring (17/23 articles), followed by educational material or training (15/23 articles) and counseling (14/23 articles). Less frequently used intervention components were quizzes (3/23 articles) and interactive feedback from a device (4/23 articles). In addition, 5 studies reported that intervention development was guided by a specific theory.

Table 1. Quality appraisal scores on the Crowe Critical Appraisal Tool.

Study	Total score (maximum=40)	Star score[a]	Preamble	Introduction	Design	Sample	Data	Ethic	Result	Discussion
van Lint et al (2015) [73]	33	4-star	4	4	4	4	4	4	4	5
Blakeman et al (2014) [70]	32	4-star	5	4	4	5	3	3	4	4
Ong et al (2016) [75]	32	4-star	4	4	4	4	4	4	4	4
Forni Ogna et al (2013) [66]	31	3-star	5	4	3	4	3	4	4	4
Ishani et al (2016) [34]	31	3-star	4	4	4	4	3	3	4	4
Stark et al (2011) [63]	30	3-star	4	4	4	4	3	3	4	4
McGillicuddy et al (2013) [36]	30	3-star	4	4	4	4	3	3	4	4
Hayashi et al (2017) [76]	30	3-star	5	4	3	3	4	3	4	4
Diamantidis et al (2013) [65]	29	3-star	5	4	4	3	3	4	3	3
Reese et al (2017) [35]	29	3-star	5	5	4	3	2	2	3	5
Dey et al (2016) [74]	28	3-star	3	4	3	3	3	4	4	4
Berman et al (2011) [59]	27	3-star	5	4	3	3	2	3	4	3
Rifkin et al (2013) [33]	27	3-star	5	4	3	4	3	2	3	3
Welch et al (2013) [69]	27	3-star	3	4	4	3	3	3	4	3
Connelly et al (2012) [64]	26	2-star	5	5	3	4	3	1	2	3
Neumann et al (2013) [68]	26	2-star	3	4	3	3	3	4	3	3
Liu et al (2017) [77]	25	2-star	4	5	3	2	3	1	3	4
Diamantidis et al (2015) [72]	24	2-star	3	4	3	4	1	3	3	3
Minatodani et al (2013) [58]	23	2-star	3	4	2	1	3	4	3	3
Sevick et al (2005) [60]	22	2-star	3	4	3	2	2	2	3	3
Harrington et al (2014) [71]	20	1-star	3	4	2	3	3	0	3	2
Gallar et al (2007) [61]	18	1-star	2	2	3	2	1	3	2	3
Heiden et al (2013) [67]	18	1-star	3	4	3	1	1	0	3	3
Whitten et al (2008) [62]	14	1-star	2	4	1	1	1	0	1	4

[a] 1-star: more than 1 SD below mean; 2-star, between 1 SD below mean and mean; 3-star, between mean and 1 SD above mean; 4-star, more than 1 SD above mean.

Table 2. Descriptions of electronic health for each report included in the review.

Category of eHealth[a]	Detailed eHealth	Functionality
Personal digital assistant (references)		
Sevick et al (2005) [60]	Dietary self-Monitoring: meals logs	Record
Stark et al (2011) [63]	Dietary self-Monitoring: meals logs	Record
Connelly et al (2012) [64]	Dietary intake monitoring: self-monitor diet and feedback	Record
Forni Ogna et al (2013) [66]	Electronic medication event monitoring: monitor adherence	Record; communicate
Welch et al (2013) [69]	Dietary intake monitoring: self-monitor diet and feedback	Display; record
Diamantidis et al (2015) [72]	Medication inquiry system: identifying the safety of medications with impaired renal function	Record; display; alert
Telemedicine (references)		
Gallar et al (2007) [61]	Videoconferencing: connecting home to hospital	Communicate
Whitten et al (2008) [62]	Videoconferencing: connecting clinics and health system	Communicate; education
Computer (references)		
Harrington et al (2014) [71]	Tablet computer: recording data and reviewing medical findings	Display; record; communicate; alert
Ishani et al (2016) [34]	Touch screen computer with peripherals	Record; communicate
Heiden et al (2013) [67]	Educational tool, food analyzer database and diet registration, and decision support to binder dosage	Communicate; education; record
Multiple components (references)		
Diamantidis et al (2013) [65]	Alert accessories linked to website/safe kidney care: offering information	Record; education
McGillicuddy et al (2013) [36]	BP[b] monitoring, electronic medication tray, and mobile phone	Alert; communicate
Minatodani et al(2013)[58], Berman et al (2011)[59]	Self-monitoring devices	Record; communicate
Blakeman et al (2014) [70]	Website: tailoring access to community resources	Display; communicate
Dey et al (2016) [74]	Computer tablet, wearable devices, and Web portal	Record; alert
Ong et al (2016) [75]	Smartphone, a Web-based dashboard application and a data server	Record; alert; display
Hayashi et al (2017) [76]	Self-management and recording system for dialysis (wearable devices, smartphone, and administrator module)	Record; alert; display
Liu et al (2017) [77]	App installed on mobile, cloud server, and Web app	Record; alert; communicate
Wearable devices (references)		
Neumann et al (2013) [68]	Telemetric weight monitoring	Display; alert
Rifkin et al (2013) [33]	BP monitoring	Record
van Lint et al (2015) [73]	BP monitoring and creatine monitoring	Record
Reese et al (2017) [35]	Wireless pill bottle	Record; alert

[a] eHealth: electronic health.

[b] BP: blood pressure.

Table 3. Descriptions of electronic health self-management interventions for each report included in the review.

Category of electronic health	Intervention components										Theory-based
	Educational material or training	Plan/ goals	Self-monitoring	Interactive feedback from device	Message/ alert to health caregivers	Message/ alerts to patients from device	Message/ alert to patients from health caregivers	Quizzes	Counseling	Daily use	
Personal digital assistant (references)											
Sevick et al (2005) [60]	✓	✓	✓	—[a]	—	—	✓	—	✓	✓	✓
Stark et al (2011) [63]	✓	✓	✓	—	—	—	✓	—	✓	✓	✓
Connelly et al (2012) [64]	✓	—	✓	✓	—	—	—	—	✓	—	✓
Forni Ogna et al (2013) [66]	—	✓	—	—	—	—	—	—	✓	—	—
Welch et al (2013) [69]	✓	—	✓	—	—	—	—	—	✓	—	✓
Diamantidis et al (2015) [72]	✓	—	—	✓	—	✓	—	—	—	—	—
Total (N=6), n (%)	5 (83)	3(50)	4 (67)	2 (33)	0	1 (17)	2 (33)	0	5 (83)	2(33)	4 (67)
Telemedicine (references)											
Gallar et al (2007) [61]	—	—	—	—	—	—	—	—	✓	—	—
Whitten et al (2008) [62]	—	—	—	—	—	—	—	—	✓	—	—
Total (N=2), n (%)	0	0	0	0	0	0	0	0	2 (100)	0	0
Computer (references)											
Harrington et al (2014) [71]	—	✓	✓	—	✓	—	✓	—	—	✓	—
Ishani et al (2016) [34]	✓	✓	✓	—	—	—	✓	—	—	—	—
Heiden et al	—	—	✓	—	—	—	—	—	—	—	—

(2013) [67]											
Total (N=3), n (%)	1 (33)	2(67)	3 (100)	0	1 (33)	0	2 (67)	0	0	1 (33)	0
Multiple components (references)											
Diamantidis et al (2013) [65]	✓	—	—	—	—	—	—	—	—	—	—
McGillicuddy et al (2013) [36]	✓	✓	✓	—	✓	✓	✓	—	✓	✓	✓
Minatodani et al(2013)[58], Berman et al (2011)[59]	✓	✓	✓	—	—	—	✓	✓	✓	—	—
Blakeman et al (2014) [70]	✓	—	—	—	—	—	—	—	✓	—	—
Dey et al (2016) [74]	✓	—	✓	—	✓	—	✓	✓	✓	—	—
Ong et al (2016) [75]	✓	✓	✓	✓	✓	✓	—	—	—	—	—
Hayashi et al (2017) [76]	—	✓	✓	—	—	✓	✓	—	✓	✓	—
Liu et al (2017) [77]	—	—	✓	—	—	✓	—	✓	—	—	—
Total (N=8), n (%)	6 (75)	4 (50)	6 (75)	1 (13)	3 (38)	4 (50)	4 (50)	3 (38)	5 (63)	2 (25)	1 (13)
Wearable devices (references)											
Neumann et al (2013) [68]	—	✓	✓	—	✓	—	✓	—	✓	✓	—
Rifkin et al (2013) [33]	✓	—	✓	—	—	—	✓	—	✓	—	—
van Lint et al (2015) [73]	✓	✓	✓	—	—	—	—	—	—	—	—
Reese et al (2017) [35]	✓	✓	✓	✓	✓	✓	✓	—	—	—	—
Total (N=4), n (%)	3 (75)	3 (75)	4 (100)	1 (25)	2 (50)	1 (25)	3 (75)	0	2 (50)	1 (25)	0

[a] Not applicable.

Summary of Results

Tables 4 and 5 present the outcome indicators and the data collection tools used. Moreover, full details on the efficacy data reported in the included studies are included in Additional file 5 (https://www.jmir.org/2019/11/e12384/). Table 6 displays the determinants of implementation extracted. No articles reported any adverse outcomes of eHealth self-management interventions.

Description of Effect Outcome Indicators

The effect outcome indicators most frequently reported were laboratory tests (e.g. serum albumin; 6/23 articles) and blood pressure (BP; 5/23 articles). Interdialytic weight gain (4/23 articles), QoL (4/23 articles), and medication adherence (4/23 articles) were also frequently reported. Finally, 2 studies assessed effects on morbidity and mortality, 2 evaluated changes in medical cost, and 1 performed a cost-effectiveness analysis. Out of 5 studies, 4 [36, 68, 70, 75] reported a statistically significant positive effect on BP. Of the 2 studies [59, 61] that evaluated changes in medical costs, 1 [59] reported a significant reduction in costs in the intervention group. A study reported an incremental cost-effectiveness ratio of US$175, showing that the implementation of a website-based self-management intervention for CKD patients was superior, considering effects and costs, to usual care [70]. Out of 3 studies, 2 [59, 61] reported statistically significant improvements in hospitalization rates and emergency room visits. Out of 4 studies, 3 [35, 36, 66] reported statistically significant improvements in patients' medication adherence. Out of 4 studies, 1 [70] reported a statistically significant improvement on QoL.

Description of Process Outcome Indicators

The process outcome indicator *satisfaction* was reported in one-third of included studies. A total of 2 studies [58, 75] used interviews to evaluate satisfaction in patients or care providers. Patients were reported to be satisfied with the use of at-home telehealth and appreciated its utility in managing their health [58]. Patients using a smartphone-based self-management system indicated feeling more confident and more in control of their condition; the nurses found that the system helped prioritize patients who needed more attention [75]. A total of 5 studies used questionnaires to evaluate satisfaction of patients [36, 71, 72, 74, 76]. These studies reported patients were highly satisfied with eHealth self-management interventions. Acceptability was also frequently reported and mostly measured using questionnaires, retention rates, or system data [33, 36, 69, 74-76] (6/23 articles). All these studies reported that eHealth self-management interventions were acceptable to patients [33, 36, 69, 74-76] and care providers [33, 36]. Other process outcome indicators (such as adherence to the intervention) were less frequently used.

Table 4. Summary of outcome indicators of electronic health self-management interventions.

Outcome category and indicator	Total number of articles in each category	Effect and references		
		Positive, n (%)	No statistically significant effect, n (%)	Mixed, n (%)
Patient effect outcome (N=33)				
Blood pressure	5	4 (80) [36, 68, 70, 75][a]	1 (20) [33]	0 (0)
Quality of life	4	1 (25) [70][a]	2 (50) [59, 74]	1 (25) [76]
Laboratory tests	6	2 (33) [66, 68][a]	4 (67) [60, 62, 75, 76]	0 (0)
Interdialytic weight gain	4	1 (25) [68][a]	3 (75) [60, 69, 76]	0 (0)
Morbidity and mortality	2	0 (0)	2 (100) [34, 61]	0 (0)
Hospitalization rate and emergency room visit	3	2 (67) [59, 61][a]	1 (33) [34]	0 (0)
Medical cost	2	1 (50) [59][a]	1 (50) [61]	0 (0)
Cost-effectiveness	1	1 (100) [70][a]	0 (0)	0 (0)
Nutrition and dietary intake	2	0 (0)	2 (100) [62, 69]	0 (0)
Medication adherence	4	3 (75) [35, 36, 66][a]	1 (25) [33]	0 (0)
Process outcome (N=28)				
Acceptability	6	6 (100); [69, 74, 76][b]; [33, 36, 75][c]	0 (0)	0 (0)
Usability	5	5 (100); [64, 67, 76][b]; [62, 77][c]	0 (0)	0 (0)
Satisfaction	8	8 (100); [36, 58, 71-74, 76][b]; [75][c]	0 (0)	0 (0)
Adherence to intervention	4	4(100); [35, 63, 73, 75] [b]	0 (0)	0 (0)
First entry and length of dwell time	1	1 (100); [65] [b]	0 (0)	0 (0)
Self-efficacy	1	0 (0)	1 (100); [69] [b]	0 (0)
Perceived benefits	1	0 (0)	1 (100); [69] [b]	0 (0)
Perceived control	1	1 (100); [69][a, b]	0 (0)	0 (0)
Recorded errors	1	1 (100); [72][b]	0 (0)	0 (0)

[a] Statistically significant.

[b] Outcome related to patient.

[c] Outcome related to both patient and care provider.

Table 5. Summary of reported tools of outcome indicators.

Outcome category and indicator	Reported data collection tools (number of articles)
Patient effect outcome (N=33), all quantitative	
Blood pressure	Readings (4) and dataset (1)
Quality of life	36-item Short Form Health Survey (1), EuroQoL-5 Dimension (1), and 36-item Kidney Disease Quality of Life survey (2)
Laboratory tests	Medical records (6)
Interdialytic weight gain	Medical records (4)
Morbidity and mortality	Charlson comorbidity index (1) and records (1)
Hospitalization rate and emergency room visit	Records (3)
Medical cost	Records (2)
Cost-effectiveness	Records (1)
Nutrition and dietary intake	Clinical data (2)
Medication adherence	System data (2), adherence score calculation (1), and Morisky Medication Adherence Scale (1)
Process outcome (N=28)	
Acceptability	Quantitative: questionnaires (1), recruitments and participation rate (1), QUEST[a] and retention rates (1), and average number of daily entries and completion rates (2); quantitative and qualitative: number of assessments and semistructured interview (1)
Usability	Quantitative: survey (1) and questionnaire (2); qualitative: interview (1); quantitative and qualitative: survey, interview, and system data (1)
Satisfaction	Quantitative: questionnaires and QUEST (5); qualitative: semistructured interview (2); quantitative and qualitative: questionnaire and interview (1)
Adherence to intervention	Quantitative: system data (3) and Basel Assessment of Adherence to Immunosuppressive Medications Scale (1)
First entry and length of dwell time	Quantitative: frequency and number (1)
Self-efficacy	Quantitative: cardiac diet self-efficacy and Fluid Self-Efficacy Scale (1)
Perceived benefits	Quantitative: Benefits of Sodium Adherence and a 9-item Benefits of Fluid Adherence Scale (1)
Perceived control	Quantitative: 7-item Mastery scale (1)
Recorded errors	Quantitative: questionnaire and record (1)

[a] QUEST: Quebec user evaluation of satisfaction with assistive technology.

Table 6. Determinants of the implementation of electronic health self-management interventions for chronic kidney disease.

Determinants of interventions and details	References	
	If determinant is present	If determinant is exact opposite
Sociopolitical context (patient)		
Awareness of potential health benefits of the eHealth[a] self-management intervention	[59], [76]	—[b]
Target population feels comfortable about eHealth use	[76], [77]	—
Organization (patient)		
Community resources (e.g. activities, services, and applicable wireless fidelity connection at the users' location) available for implementation	[70]	[71]
User		
Patient		
Support from colleagues (e.g. internet personnel)	[63]	[36]
Ability of health care professionals to monitor and, if necessary, anticipate on patient measurements online	[33], [35], [59], [73], [75], [77]	—
Availability of sufficient skills/knowledge	[72]	[59], [69]
eHealth technology is considered valuable by user	[36], [67], [70]	[73]
High self-efficacy	[73]	—
Patient and care provider		
eHealth technology is considered valuable by user	[33]	—
Innovation		
Patient		
Implementation of intervention is perceived as risk-free by user	[71], [74], [76]	—
Provision of warning/alert/reminder based on parameters monitored	[35], [36], [73]	—
Provision of real-time feedback (e.g. amount of dietary intake, blood pressure value) based on patients' input	[60], [63], [64], [76]	—
Perceived quality of eHealth intervention is excellent	—	[33], [36], [59], [71]
Patient and care provider		
Interventions are compatible with existing work procedures	[33]	—
Implementation of intervention is perceived as advantageous by patient and care providers considering increasing access to health care services	[62]	—
High acceptability of eHealth	[33]	—
Perceived quality of eHealth intervention is excellent	[61]	—
Innovation strategies (patient and care provider)		
Well planned/structured implementation process	[77]	—

[a]eHealth: electronic health. [b]Not applicable.

Description of Implementation Determinants

All but 4 studies [34, 65, 66, 68] reported on determinants of implementation. Studies included used various methods (e.g. qualitative interview and quantitative data analysis) to evaluate determinants of implementation. The determinant *ability of health care professionals to monitor and, if necessary, anticipate on patient measurements online* is mostly reported to make patients feel safe while using eHealth interventions [77], thereby influencing patients' medication adherence [35] and adherence to interventions [35, 73]. Moreover, *availability of sufficient skills/knowledge* [58, 69, 72] was reported as an important determinant to patients' use of the eHealth self-management interventions. In addition, the determinant *provision of real-time feedback based on patients' input* was frequently reported to influence patients' adherence to self-monitoring and healthy behaviors [60, 63, 64, 76]. The determinant *perceived quality of eHealth intervention is excellent* [61] was cited to influence both patients' and care providers' use of the intervention. The percent agreement between the 2 reviewers' classification of the implementation determinants reported following the Fleuren framework was 76%, which is considered acceptable [48]. Discrepancies in classification were discussed until consensus was reached.

DISCUSSION

Principal Findings

The main findings and implications have been presented in Textbox 3.

Textbox 3. Main findings and implications for this study.

- Although the evidence base is still inconclusive, a majority of studies on electronic health (eHealth) self-management interventions report improvements on proximal outcomes (e.g. blood pressure controlling) and mixed effects for more distal (e.g. quality of life) outcomes.
- Evidence on the process level is more established; eHealth self-management interventions for chronic kidney disease patients are reported to be highly feasible, usable, and acceptable.
- To adequately assess eHealth intervention effect, future researchers should carefully consider their choice of outcomes (distal vs proximal) based on their sensitivity to capture meaningful change.
- Standardization of research design and methods in the evaluation of eHealth self-management interventions for chronic kidney disease patients is needed to optimize quality and comparability across studies and further elucidate which intervention components alone or in interaction contribute to the promising results found.

The evidence regarding the implementation and effectiveness of eHealth self-management interventions for CKD patients was reviewed. The 23 studies included were appraised on methodological quality, and all relevant data were extracted. Although the evidence base is still inconclusive, our review provides an indication that eHealth self-management interventions have the potential to improve CKD patients' management and health outcomes. Furthermore, high acceptability of and satisfaction with the eHealth interventions used were reported. Owing to the heterogeneity of the intervention components and outcomes measures used, we could not determine which intervention components contributed most to the effects found. The determinant *ability of health care professionals to monitor and, if necessary, anticipate on patient measurements online* was most frequently reported to influence implementation. The determinants reported were not quantified, and the relative importance of each determinant could not be determined.

Comparison of Findings

Most studies reported the evaluation of effect outcome indicators. The positive effects on patients' BP controlling [36, 68, 70, 75] and medication adherence [35, 36, 66] were consistently reported; no adverse outcomes were reported. These findings correspond with another review on eHealth interventions in CKD [39]. Compared with standard outpatient-based management, eHealth self-management interventions have the potential to reduce health care delivery costs [78]. Although this potential reduction in costs is essential for policy makers and clinicians to adopt eHealth self-management interventions, health care expenditures were only assessed in 3 of the studies included, with only 1performing a cost-effectiveness analysis [70]. Hence, we cannot yet determine if and how these interventions might reduce medical costs. This finding is consistent with similar reviews, which conclude that studies on the cost-effectiveness of eHealth self-management interventions are either conflicting or lacking [32, 54]. As evidence on cost-effectiveness is important to support the potential scale-up of eHealth technology, further research is needed to broaden this evidence base. Regarding QoL, only 1 out of 4 studies reported a significant improvement. A possible explanation for this finding was the short follow-up period instated to capture changes in a distal outcome such as QoL [59]. As QoL in CKD is an independent predictor of mortality and hospitalization [79, 80], and thus important to evaluate, we advise further research to assess QoL with a longer follow-up period.

In general, we found that eHealth self-management interventions were reported to be highly feasible, usable, and acceptable. However, we found great diversity in the use and operationalization of outcome indicators and how they were measured. For instance, a study reported acceptability by measuring adoption, adherence to the recommended intervention use, user satisfaction, and feature usage [75]. In contrast, other studies [33,36] measured acceptability by asking patients "how acceptable they found the intervention” using a self-report scale. It is also notable that only 4 studies assessed implementation adherence, although finding no or limited intervention effects can be strongly related to patients’ nonadherence to eHealth interventions as prescribed [81, 82]. Examining implementation adherence can help resolve the *black box* of patients’ adoption and continued use of the intervention, thereby preventing a type 3 error [83]. To tackle these issues, we advise researchers to use a standardized operationalization of process outcome indicators and measure implementation adherence to enable reliable interpretation of the intervention effect found.

Considering which outcomes are most sensitive to change is important. As eHealth interventions studies are mostly of short duration, they may not detect changes in distal outcomes (e.g. QoL). Hence, effectivity might be easier to detect when proximal outcomes, close to the intervention strategies, are measured. For example, BP controlling can be an outcome sensitive to change if self-monitoring is the main intervention component. Functional outcomes (such as days needed to return to work), which can quantify patients’ subjective perceptions of the effect of treatment on their daily life, might also be very sensitive to change by eHealth interventions [84, 85]. Moreover, researchers should consider if their outcomes reflect meaningful change and provide a clear rationale for their choice of laboratory parameters. For example, using serum albumin as an indicator for dietary adherence might be of limited value as it is influenced by other CKD characteristics (e.g. low dialysis dose) [60].

Furthermore, improving knowledge on the effect modifiers at play in eHealth self-management interventions for CKD patients is important. None of the included studies provided detail on potentially relevant effect modifiers. We can identify some possible modifying factors based on research focusing on self-management interventions in other chronic, noncommunicable diseases (NCDs). For instance, a longer intervention duration might positively modify the effect of self-management interventions [86]. In addition, the patients’ health literacy level might modify intervention effect [87]. Self-management interventions for NCDs are mostly based on similar intervention principles and behavior change techniques. Moreover, the characteristics of patients suffering from NCDs are often similar. We, therefore, argue that the modifiers found to influence the outcomes of self-management interventions for NCDs in general might also be applicable for similar interventions targeting CKD patients. However, more research is needed to identify effect modifiers to self-management interventions targeting CKD and explore possible strategies to impact these factors.

Electronic Health Self-Management Interventions

A large variety of eHealth self-management intervention components were used in the included studies (e.g. self-monitoring and education), and the results differed greatly. These findings make it difficult and possibly premature to formulate a potentially ideal palette of eHealth self-management intervention components for CKD patients. However, reviewing results make it possible to identify which intervention components might be more promising than others. For instance, self-monitoring and the use of messages or alerts to nudge patient toward displaying healthy behaviors (see Additional file 6: https://www.jmir.org/ 2019/11/e12384/) were most commonly reported as the effective components to optimize patient self-management skills.

Furthermore, few of the interventions studied were theory-based. The authors recommend that a strong theoretical foundation is necessary for the planning, design, evaluation, and implementation of eHealth self-management interventions [88].We recommend building eHealth self-management interventions based on established behavior change techniques, such as formulated in the Behavior Change Techniques taxonomy [55]. Moreover, the use of cocreation methods and appreciative inquiry (such as described in the Center for eHealth Research and Disease Management [89] roadmap for eHealth development) can improve intervention fit with the needs and priorities expressed by professionals and patients.

Determinants of Implementation

Ability of health care professionals to monitor and, if necessary, anticipate patient measurements online was reported as an important determinant of implementation. We argue that this ability of professionals to anticipate and act upon patient measurements might reduce patients' feeling of isolation and/or anxiety caused by independently conducted treatments at home [77] and thereby increase patients' adherence to implementation. In addition, *availability of sufficient skills/knowledge* was important for users to continue their use of eHealth technology. If participants are unfamiliar with the use of eHealth, this has been reported to limit their acceptance of eHealth interventions [58, 69]. Proper training and tailored tutorials are needed to guide eHealth implementation to optimize knowledge and skills and promote intervention uptake [67, 72]. The included studies used various methods to evaluate determinants of implementation. We suggest that future research should use validated tools for measuring implementation quality and related determinants, such as the Measurement Instrument for Determinants of Innovations questionnaire and Determinants of Implementation Behavior Questionnaire [90, 91].

Study Quality and Characteristics

Most studies were appraised to be of low to moderate quality. There is a heterogeneity of outcome measurement tools and reporting styles used in the articles included in this review. Therefore, we advise researchers to develop a more standardized approach to the use of outcome measures, guided by, for instance, the formulation of an International Consortium for Health Outcomes Measurement standard set for CKD [92]. In addition, we argue that detailed description and a thorough analysis of study design, methods, and intervention components used, based on a published theoretical framework such as Consolidated Standards of Reporting Trials-eHealth [93], can improve reporting and provide a basis for evaluating the validity and applicability of eHealth trials.

Data on eHealth self-management interventions for CKD patients in developing countries are still lacking, which corresponds with other reviews on eHealth interventions [94, 95]. The need to perform such research in developing countries is high. eHealth interventions in these countries have the potential to improve the accessibility and cost-effectiveness of local care and ensure timely delivery of care to rural areas and diverse populations [20, 24, 96]. Furthermore, 9 studies had an intervention duration of fewer than 6 months. Few studies conducted a follow-up measurement. Forni Ogna et al [66] reported that the positive intervention effects were maintained only during the monitoring period; these effects had vanished 3 months after interruption of the drug adherence monitoring. This finding underlines that the effectiveness of eHealth self-management interventions should be tested during a longer study period and with follow-up measurements.

Of note, 3 studies with fewer than 10 participants were included. One might argue that such studies do not provide robust, generalizable evidence and should be excluded based only on their sample size. However, high-level evidence on the effectiveness of eHealth self-management interventions for CKD patients, for instance, generated by large RCTs, is very limited. Hence, studies with less robust designs are included, as in this stage, we feel that all evidence should be accumulated and taken into account as to broaden our view and deepen our understanding of the usability, implementability, and effectiveness of eHealth self-management interventions for CKD patients. Moreover, this decision is supported by similar systematic reviews on the effectivity of eHealth interventions that also included studies with smaller sample sizes [95, 97, 98]. That being said, results of this review should be interpreted with some caution.

Strengths and Limitations

To our knowledge, this is the first systematic review to evaluate the entire spectrum of studies focusing on eHealth self-management interventions for CKD patients. Our review has some strengths. First, PRISMA guidelines were followed, and a robust search strategy was used in 8 databases. Second, a comprehensive analysis was conducted on the intervention components, outcome indicators, and determinants from the various studies. The kappa value and percent agreement obtained, and thus inter-rater reliability, showed that the validity of the appraisal could be considered fair. Finally, any discrepancies were discussed until consensus was reached.

Nevertheless, several limitations need to be addressed. First, as articles only published in English were included, some relevant articles might have been missed. Second, substantial heterogeneity of interventions and outcome measures made it difficult to draw firm conclusions about the evidence emerging from these studies, and results should be interpreted with caution.

CONCLUSIONS

This review provides a comprehensive overview of studies evaluating eHealth self-management interventions for CKD patients. eHealth self-management interventions show promise to improve health outcomes in CKD patients. To adequately assess eHealth intervention effect, future researchers should carefully consider their choice of outcomes (distal vs proximal) based on their sensitivity to capture meaningful change. Also, to enable the standard design and scale-up of effective eHealth self-management interventions for CKD patients, a more detailed understanding of which individual intervention components lead to health outcome improvement and which determinants of the implementation can promote adherence and satisfaction with care is needed.

Authors' contributions

HS led the conception and design of this study and is the main contributor in writing this manuscript. RK, PB, XC and NC contributed to the conception and design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

This study is funded by the China Scholarship Council.

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Chapter 3

Prevalence of reduced kidney function, kidney function decline and related risk factors among a primary care population in China: A repeated cross-sectional study

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Submitted

Abstract

Background

Chronic kidney disease (CKD) poses a severe health and socioeconomic burden, particularly to low-income and middle-income countries. China is the largest low-income and middle-income country with a current population of 1.4 billion. However, only a few studies reported on the prevalence of reduced kidney function and related risk factors among Chinese populations. Also, none of these studies explored the prevalence of kidney function decline and related risk factors, especially in Chinese primary care settings. To bridge this gap, this study aimed to examine the prevalence of reduced kidney function and kidney function decline and explore related risk factors in a Chinese primary care population.

Methods

We conducted a repeated cross-sectional study in a primary health care population in China. Electronic records were included of 18273 adults who underwent routine health check-ups between 2004-2020 in three primary health care centers in Zhengzhou city, Henan Province in China. Follow-up serum creatinine was available for 3314 participants, with a mean follow-up duration of 1.5 years. Reduced kidney function was defined as an estimated glomerular filtration rate (eGFR) of below 60 mL/min per 1.73 m^2. Kidney function decline was defined as a drop in the glomerular filtration rate (GFR) category (≥90 [G1], 60-89 [G2], 45-59 [G3a], 30-44 [G3b], 15-29 [G4], <15 [G5] mL/min per 1.73 m^2) accompanied by a ≥25% drop in eGFR from baseline, or a sustained decline in eGFR of >5 mL/min per 1.73 m^2/y. Rapid eGFR decline was defined as a decline in eGFR of greater than 3 mL/min/1.73m^2/y. The annual eGFR decline was calculated as ($eGFR_{baseline}$-$eGFR_{follow\text{-}up}$)/time (follow-up years). Descriptive statistics and multivariable logistic regressions were used to examine reduced kidney function, kidney function decline and related risk factors.

Results

Of all participants, 3273(17.9%) had reduced kidney function at first measurement. Of the participants with a follow-up, 640 (19.3%) had kidney function decline and 755 (22.8%) had rapid eGFR decline. Multivariable logistic regression analysis showed that female sex (OR 2.208, 95% CI 1.974-2.470), older age (OR 1.051, 95% CI 1.046-1.057), hypertension (OR 0.847, 95% CI 0.719-0.997), overweight (OR 1.162, 95% CI 1.042-1.296), obesity (OR 1.609, 95% CI 1.349-1.919), diabetes (OR 1.229, 95% CI 1.043-1.447), left ventricular hypertrophy (OR 2.123, 95% CI 1.407-3.203), and dyslipidemia (OR 2.478, 95% CI 2.086-2.943) were independent predictors of reduced kidney function. Moreover, older age (OR 1.013, 95% CI 1.002-1.023) and a reduced kidney function at baseline (OR 11.133, 95% CI 7.827-15.836) were independent predictors of kidney function decline.

Conclusions

Our study demonstrated a high prevalence of reduced kidney function and kidney function decline in a Chinese primary care population. Also, the identified associated risk factors can help to identify those who are more likely to experience a reduced kidney function and kidney function decline. To reduce the burden of CKD in China, effective three-level prevention and treatment strategies seem warranted.

INTRODUCTION

Chronic kidney disease (CKD) is a major public health concern [1, 2]. Globally, 698 million individuals are affected by CKD [3]. Also, CKD is associated with adverse outcomes including kidney failure, accelerated cardiovascular disease (CVD) and premature death [4, 5]. In specific, a recent study reported that globally, 1.4 million CVD-related deaths and 25.3 million CVD disability-adjusted life years are attributable to impaired kidney function [3].

The burden of CKD is particularly high in low-income and middle-income countries [6], including China, with an estimated prevalence of 10.8% (120 million adults) [7]. To reduce this burden, the identification of potentially modifiable risk factors for reduced kidney function [8] is essential to enable the prevention of CKD progression in an early stage. Previous evidence indicates that diabetes, hypertension and dyslipidemia can play an important role in the development of reduced kidney function [9, 10]. Also, minimal, moderate, or rapid rates of estimated glomerular filtration rate (eGFR) decline can predict premature mortality [11-13]. Some of the previous studies reported CKD progression and related risk factors [10, 14], yet only a few studies reported on prevalence of reduced kidney function and related CVD risk factors for the Chinese population [15-17]. Also, none of these studies explored the prevalence of kidney function decline and related CVD risk factors, especially in Chinese primary care settings. Related definitions of reduced kidney function and kidney function decline are operationalized based on previous literature [18, 19] and further detailed in Textbox 1.

Better insights into the prevalence of reduced kidney function and kidney function decline in the Chinese primary care population is of vital importance to assess the burden of CKD in Chinese settings. Evidence on the burden of CKD can adequately inform public health policymakers, healthcare professionals, and community members on the impact of CKD. Also, identifying (modifiable) risk factors for reduced kidney function and kidney function decline has practical relevance to developing target effective strategies. Therefore, we performed a repeated cross-sectional study to examine the prevalence of reduced kidney function and kidney function decline and explore related risk factors in China.

Textbox 1. Definitions of reduced kidney function and kidney function decline.

Reduced kidney function

- An estimated glomerular filtration rate (eGFR) of below 60 mL/min per 1.73 m^2 is a widely used indicator of reduced kidney function [19].
  eGFR was calculated using the Chronic Kidney Disease Epidemiology Collaboration (CKD-EPI) study equation [20]: $eGFR = 141 \times \min(Scr/\kappa, 1)^{\alpha} \times \max(Scr/\kappa, 1)^{-1.209} \times 0.993^{Age} \times 1.018$ [if female], where Scr is serum creatinine, κ is 0.7 for females and 0.9 for males, α is -0.329 for females and -0.411 for males, min indicates the minimum of Scr/κor 1, and max indicates the maximum of Scr/κ or 1.

Kidney function decline and rapid eGFR decline

- CKD is categorized in five stages (CKD stages G1–G5) based on the eGFR [19]. Kidney function decline [18, 19] was defined as a drop in the glomerular filtration rate (GFR) category (≥90 [G1], 60-89 [G2], 45-59 [G3a], 30-44 [G3b], 15-29 [G4], <15 [G5] mL/min per 1.73 m^2) accompanied by a ≥25% drop in eGFR from baseline, or a sustained decline in eGFR of >5 mL/min per 1.73 m^2/y. Rapid eGFR decline was defined as a decline in eGFR of greater than 3 mL/min/1.73m^2/y [18, 19]. The annual eGFR decline was calculated as ($eGFR_{baseline}$-$eGFR_{follow\text{-}up}$) /time (follow-up years).

METHODS

Study Design, setting and population

We performed a repeated cross-sectional study and accumulated data of routine health check-ups in a large primary care population between 2004-2020 in three primary health care centers in Zhengzhou City. Zhengzhou, the capital city of one of the biggest provinces in China (Henan), has a population of nearly 10 million. Participants could receive health check-up for several reasons; (1) if they were enrolled in the general practitioner-centered primary care system in the primary health centers at the first time, they had one free health check-up; (2) if they were aged 65 years or older, they had one free annual health check-up; and (3) some people voluntarily received a health check-up when they paid for it.

A total of 69473 residents underwent health check-ups between 2004-2020 in three primary health care centers. Serum creatinine was measured for 18295 residents; electronic records were included of all residents aged ≥ 18 years old (18273 participants). Using the creatinine measurements, we calculated the eGFR using the CKD-EPI study equation [20]. Follow-up data of serum creatinine measurement was available for 3314 participants (18%), with a mean follow-up duration of 1.5 years (study flow diagram in Figure 1). We followed the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement [21] to report our study.

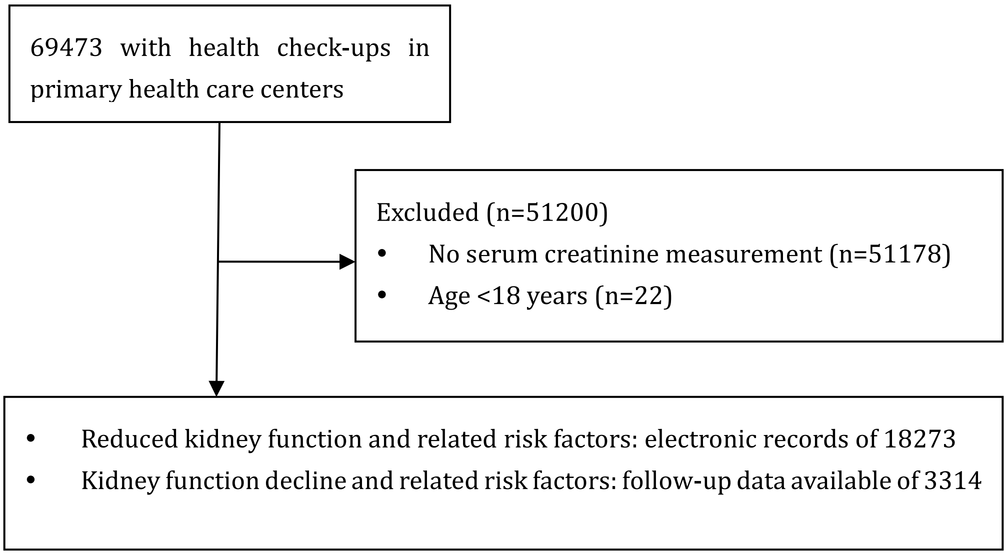

Figure 1． Study flow diagram.

Measurements

The health check-up results were entered into patient health care records by the patients' physicians. The health check-up data include information on demographic characteristics (age, sex), physical examination parameters (height, weight, body temperature, pulse, breathing rate, body mass index and blood pressure), laboratory tests findings (fasting blood glucose, liver function, kidney function and the blood lipids), electrocardiogram (ECG) results and specific diagnoses made by the physicians (e.g. diagnosis of hypertension). No urine tests were performed.

An anonymized database including electronic records was available for analysis. For our study, we extracted data on age, sex, body mass index (BMI), blood pressure (BP), fasting blood glucose, total cholesterol, fasting triglyceride, serum low-density lipoprotein (LDL) cholesterol, serum high-density lipoprotein (HDL) cholesterol, serum creatinine level, ECG test results and the diagnosis made by the physician.

Definitions

Definitions of reduced kidney function and kidney function decline are provided in Textbox 1.

BMI was categorized into underweight (<18.5 kg/m^2), healthy weight (18.5-23.9 kg/m^2), overweight (24-27.9 kg/m^2) and obesity (≥28 kg/m^2) by using the Chinese "Criteria of weight for adults (No. WS/T 428-2013, available on http://www.nhfpc.gov.cn)". Hypertension was defined as an average systolic BP (SBP)≥140mmHg or an average diastolic BP (DBP)≥90mmHg or a diagnosis of hypertension by a physician [22]. Diabetes was defined as a fasting blood glucose level of ≥7.00 mmol/L or a diagnosis of diabetes by a physician [9]. Dyslipidemia was defined as the presence of one or more abnormal serum lipid concentrations according to the Chinese guidelines for the prevention and treatment of dyslipidemia in adults [23]: total cholesterol>6.22 mmol/L; fasting triglycerides>2.26 mmol/L; LDL cholesterol>4.14 mmol/L; HDL cholesterol<1.04 mmol/L. Left ventricular hypertrophy (LVH) was defined as an ECG-aided physician-diagnosis of LVH.

The total number of CVD risk factors [9] per patient was calculated based on the presence of the following: obesity, hypertension, diabetes, dyslipidemia and LVH.

Statistical analysis

All statistical analyses were performed using SPSS version 23 (IBM, Armonk, NY, USA). Descriptive analyses were performed, calculating the mean ± standard deviation (SD), median (interquartile range, IQR) and the proportions of categorical variables as appropriate. Continuous variables were compared using *t*-tests. Categorical variables were compared using Chi-square and Fisher's exact tests, as appropriate.

In the database of electronic records of 18273 adults, data were missing for SBP (0. 1%), DBP (0.1%), BMI (0.3%), fasting blood glucose (1.5%), total cholesterol (0.6%), fasting triglyceride (0.7%), serum LDL cholesterol (19.8%) and serum HDL cholesterol (19.9%). For the follow-up electronic records of 3314 out of the total 18273 participants, data were missing for SBP (0.3%), DBP (0.3%), BMI (0.4%), fasting blood glucose (1.6%), total cholesterol (0.4%), fasting triglyceride (0.5%), serum LDL cholesterol (42.6%) and serum

HDL cholesterol (42.8%). Multiple data imputation was used to handle the missing data [24]. We compared multivariable logistic regression analyses results by using multivariable multiple imputations of 10 imputations and 20 imputations and similar results were found. Hence, we used multivariable multiple imputations with 10 imputations and assumed the data were completely missing at random. The univariable analyses were performed on the complete case data and the multivariable logistic regression analyses were performed on each imputed dataset.

Univariable and multivariable logistic regression analyses were used to explore the association between reduced kidney function and potential risk factors. In the first model, we adjusted for sex and age (per year increase). In the second model, based on the results of univariable analyses and previous literature reporting risk factors of reduced kidney function [10, 25], we additionally adjusted for hypertension (yes versus no), BMI (healthy weight [reference] versus underweight versus overweight versus obesity), diabetes (yes versus no), LVH (yes versus no), dyslipidemia (yes versus no) and the number of CVD risk factors (0 [reference] versus 1-2 versus ≥3). Similarly, we used univariable and multivariable logistic regression analyses to examine the association between kidney function decline and potential risk factors. All tests were two-sided with a significance level of P values<0.05. Also, to account for multiple testing, we used the Bonferroni correction and reported significant associations for which $P<0.05$/number of comparisons in univariable analyses.

RESULTS

Participant characteristics

Participant characteristics are shown in Table 1 and Table 2. Of all participants, 9213 (50.4 %) were aged ≥70 years and 10756 (58.9%) were female. The mean eGFR from the first measurement was 81.56±25.73 mL/min/1.73m^2.

Prevalence of reduced kidney function and kidney function decline

Of all participants, 3273 (17.9%) had reduced kidney function at first measurement. For people aged ≥60 years old, 3034 (18.8%) had reduced kidney function vs. 239 (10.7%) for people <60 years old (Table 1). Of the participants with a follow-up, 640 (19.3%) had kidney function decline and 755 (22.8%) had rapid eGFR decline (Table 2).

Factors associated with reduced kidney function

Table 1 shows that the following factors were associated with reduced kidney function: sex, age, hypertension, BMI, diabetes, LVH, dyslipidemia and the number of CVD risk factors. After applying the Bonferroni correction, hypertension was no longer significantly associated with reduced kidney function. Using univariable and multivariable logistic regression models, in the final model, female sex, older age, hypertension, overweight, obesity, diabetes, LVH and dyslipidemia were independent predictors of reduced kidney function (Table 3). When considering total cholesterol, fasting triglycerides, LDL cholesterol, HDL cholesterol as separate risk factors, the multivariable logistic regression analysis showed that female sex, older age, hypertension, overweight, obesity, diabetes, LVH, fasting triglyceride>2.26 mmol/L and serum HDL cholesterol<1.04 mmol/L were independent predictors of reduced kidney function (Additional file 1).

Factors associated with kidney function decline

Table 2 shows that the following factors were associated with kidney function decline: a reduced kidney function at baseline, sex, hypertension, dyslipidemia and the number of CVD risk factors. After applying the Bonferroni correction, hypertension and the number of CVD risk factors were no longer significantly associated with kidney function decline. Using univariable and multivariable logistic regression models, in the final model, older age and a reduced kidney function at baseline were independent predictors of kidney function decline (Table 4). When considering total cholesterol, fasting triglycerides, LDL cholesterol, HDL cholesterol as separate risk factors, the multivariable logistic regression analysis showed that older age and a reduced kidney function at baseline were independent predictors of kidney function decline (Additional file 2).

Table 1. Participants characteristics and related prevalence of reduced kidney function.

Category	No. of participants	Overall	Participants with eGFR≥60 mL/min per 1.73 m^2 (n=15000)	Participants with eGFR<60 mL/min per 1.73 m^2 (n=3273)	*P -value*
Sex	18273				<0.001
-Female, n %		10756(58.9)	8382(55.9)	2374(72.5)	
Age, mean (SD), years	18273	69.4(10.7)	68.8(10.9)	72.5(9.3)	<0.001
Age (years)					<0.001
-18-39, n %		403(2.2)	395(2.6)	8(0.2)	
-40-59, n %		1815(9.9)	1584(10.6)	231(7.1)	
-60-69, n %		6842(37.4)	5802(38.7)	1040(31.8)	
-≥70, n %		9213(50.4)	7219(48.1)	1994(60.9)	
Hypertension, n %	18250	3321(18.2)	2772(18.5)	549(16.8)	0.024
-Systolic BP, mean (SD), mmHg		129.8(12.2)	129.8(12.1)	129.7(12.4)	0.664
-Diastolic BP, mean (SD), mmHg		76.9(7.7)	76.9(7.8)	76.9(7.4)	0.862
BMI, mean (SD), kg/m^2	18217	24.5(2.9)	24.4(2.9)	24.9(3.2)	<0.001
-Healthy weight (BMI, 18.5-23.9 kg/m^2), n %		8301(45.6)	6998(46.8)	1303(40.1)	<0.001
-Underweight (BMI<18.5 kg/m^2), n %		256(1.4)	222(1.5)	34(1.0)	0.054
-Overweight (BMI, 24-27.9 kg/m^2), n %		7563(41.5)	6181(41.3)	1382(42.5)	0.217
-Obesity (BMI≥28 kg/m^2), n %		2097(11.5)	1563(10.4)	534(16.4)	<0.001
Diabetes (FBG≥7 mmol/L), n %	18005	2395(13.3)	1864(12.6)	531(16.4)	<0.001
-FBG, mean (SD), mmol/L		5.9(2.4)	5.9(2.2)	6.2(3.2)	<0.001

Left ventricular hypertrophy, n %	17293	167 (1)	122(0.9)	45(1.5)	0.002
Dyslipidemia, n %	15541	5053(32.5)	4152(30.6)	901(45.2)	<0.001
-Total cholesterol>6.22 mmol/L	18163	1632(9.0)	1215(8.2)	417(12.8)	<0.001
-Fasting triglyceride>2.26 mmol/L	18153	2893(15.9)	2431(16.2)	462(14.2)	0.002
-Serum LDL cholesterol>4.14 mmol/L	14660	601(4.1)	521(4.0)	80(5.2)	0.019
-Serum HDL cholesterol<1.04 mmol/L	14631	1315 (9)	1150(8.8)	165(10.9)	0.006
No. of CVD risk factors	14568				<0.001
-0, n %		6794(46.6)	6175(48.5)	619(33.8)	
-1, n %		5107(35.1)	4401(34.5)	706(38.6)	
-2, n %		2080(14.3)	1692(13.3)	388(21.2)	
-3, n %		521(3.6)	420(3.3)	101(5.5)	
-4, n %		65(0.4)	50(0.4)	15(0.8)	
-5, n %		1(0)	1(0)	0(0)	

Abbreviations: eGFR: estimated glomerular filtration rate; BP: blood pressure; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease.

Table 2. Participants characteristics and related presence of kidney function decline.

Category	No. of participants	Overall	No kidney function decline (n=2674)	With kidney function decline (n=640)	*P*-value
Baseline eGFR, mean (SD), mL/min per 1.73 m²	3314		66.9 (20.1)	90.3(41.3)	<0.001
Reduced kidney function at baseline, n %	3314	2172(65.5)	1568(58.6)	604(94.4)	<0.001
Sex	3314				0.001
-Female, n %		2051(61.9)	1693(63.3)	358(55.9)	
Age, mean (SD), years	3314	69.9(9.1)	69.9(9.0)	69.6(9.3)	0.477
Age (years)	3314				0.709
-18-39, n %		15(0.5)	11(0.4)	4(0.6)	
-40-59, n %		307(9.3)	244(9.1)	63(9.8)	
-60-69, n %		1390(41.9)	1116(41.7)	274(42.8)	
-≥70, n %		1602(48.3)	1303(48.7)	299(46.7)	
Hypertension, n %	3304	603(18.3)	469(17.6)	134(21.0)	0.045
-Systolic BP, mean (SD), mmHg		130.2(12.5)	130.2(12.1)	130.2(14.0)	0.981
-Diastolic BP, mean (SD), mmHg		77.4(7.5)	77.5(7.3)	76.9(8.4)	0.141
BMI, mean (SD), kg/m²	3301	24.8 (3.1)	24.9(3.1)	24.6(3.1)	0.076
-Healthy weight (BMI, 18.5-23.9 kg/m²), n %		1323(40.1)	1050(39.4)	273(42.7)	0.129

-Underweight (BMI<18.5 kg/m^2), n %		48(1.5)	35(1.3)	13(2.0)	0.172
-Overweight (BMI, 24-27.9 kg/m^2), n %		1449(43.9)	1178(44.3)	271(42.4)	0.399
-Obesity (BMI≥28 kg/m^2), n %		481(14.6)	399(15.0)	82(12.8)	0.165
Diabetes (FBG≥7 mmol/L), n %	3260	569(17.5)	473(18.0)	96(15.3)	0.111
-FBG, mean (SD), mmol/L		6.1(2.5)	6.1 (2.5)	6.1(2.3)	0.482
Left ventricular hypertrophy, n %	3061	24(0.8)	20(0.8)	4(0.7)	0.941
Dyslipidemia, n %	2265	1093(48.3)	894(50.4)	199(40.6)	<0.001
-Total cholesterol>6.22 mmol/L	3300	356(10.8)	294(11.0)	62(9.7)	0.339
-Fasting triglyceride>2.26 mmol/L	3296	530(16.1)	429(16.1)	101(15.9)	0.894
-Serum LDL cholesterol>4.14 mmol/L	1862	52(2.8)	45(3.1)	7(1.7)	0.113
-Serum HDL cholesterol<1.04 mmol/L	1857	222(12.0)	183(12.7)	39(9.4)	0.066
No. of CVD risk factors	2050				0.041
-0, n %		635(31.0)	472(29.4)	163(36.9)	
-1, n %		887(43.3)	707(44.0)	180(40.7)	
-2, n %		422(20.6)	345(21.5)	77(17.4)	
-3, n %		96(4.7)	76(4.7)	20(4.5)	
-4, n %		10(0.5)	8(0.5)	2(0.5)	

Abbreviations: eGFR: estimated glomerular filtration rate; BP: blood pressure; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease.

Table 3. Factors associated with reduced kidney function.

Analysis	Univariable		Model 1		Model 2	
	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*
Female	2.085(1.918-2.266)	<0.001	2.185(2.008-2.377)	<0.001	2.208(1.974-2.470)	<0.001
Age (per year increase)	1.038(1.034-1.042)	<0.001	1.040(1.036-1.045)	<0.001	1.051(1.046-1.057)	<0.001
Hypertension	0.889(0.804-0.983)	0.022			0.847(0.719-0.997)	0.046
Body mass index						
-Healthy weight (BMI, 18.5-23.9 kg/m^2)	Reference				Reference	
-Underweight (BMI<18.5 kg/m^2)	0.825(0.572-1.191)	0.305			0.932(0.606-1.434)	0.750
-Overweight (BMI, 24-27.9 kg/m^2)	1.202(1.106-1.306)	<0.001			1.162(1.042-1.296)	0.007
-Obesity (BMI≥28 kg/m2)	1.833(1.635-2.056)	<0.001			1.609(1.349-1.919)	<0.001
Diabetes (FBG≥7 mmol/L)	1.361(1.225-1.511)	<0.001			1.229(1.043-1.447)	0.014
Left ventricular hypertrophy	1.726(1.224-2.435)	0.002			2.123(1.407-3.203)	<0.001
Dyslipidemia	2.572(2.348-2.816)	<0.001			2.478(2.086-2.943)	<0.001
No. of CVD risk factors						
-0	Reference				Reference	
-1-2	2.316(2.090-2.566)	<0.001			1.207(0.982-1.482)	0.073
-≥3	3.109(2.542-3.801)	<0.001			0.945(0.605-1.474)	0.801

Abbreviations: OR: odds ratio; CI: confidence interval; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease. Model 1 was adjusted for sex and age; Model 2 adjusted for sex, age, hypertension, body mass index, diabetes and left ventricular hypertrophy, dyslipidemia and no. of CVD risk factors.

Table 4. Factors associated with kidney function decline.

Analysis	Univariable		Model 1		Model 2	
	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*
Female	0.736(0.618-0.876)	0.001	0.735(0.617-0.875)	0.001	0.867(0.715-1.050)	0.143
Age (per year increase)	0.997(0.987-1.006)	0.477	0.996(0.987-1.006)	0.435	1.013(1.002-1.023)	0.018
Reduced kidney function at baseline	11.834(8.382-16.709)	<0.001			11.133(7.827-15.836)	<0.001
Hypertension	1.244(1.003-1.543)	0.047			1.074(0.746-1.545)	0.701
Body mass index						
-Healthy weight (BMI, 18.5-23.9 kg/m^2)	Reference				Reference	
-Underweight (BMI<18.5 kg/m^2)	1.414(0.738-2.710)	0.297			1.133(0.558-2.302)	0.729
-Overweight (BMI, 24-27.9 kg/m^2)	0.886(0.735-1.069)	0.208			0.913(0.744-1.122)	0.389
-Obesity (BMI≥28 kg/m2)	0.791(0.603-1.039)	0.092			1.035(0.701-1.529)	0.862
Diabetes (FBG≥7 mmol/L)	0.834(0.656-1.060)	0.138			0.907(0.637-1.292)	0.588
Left ventricular hypertrophy	0.833(0.284-2.446)	0.740			0.771(0.241-2.465)	0.660
Dyslipidemia	0.819(0.671-0.999)	0.049			0.921(0.628-1.349)	0.670
No. of CVD risk factors						
-0	Reference				Reference	
-1-2	0.847(0.691-1.038)	0.109			0.887(0.570-1.382)	0.595
-≥3	0.918(0.584-0.444)	0.713			0.923(0.320-2.661)	0.882

Abbreviations: OR: odds ratio; CI: confidence interval; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease. Model 1 was adjusted for sex and age; Model 2 adjusted for sex, age, hypertension, body mass index, diabetes and left ventricular hypertrophy, dyslipidemia and no. of CVD risk factors.

DISCUSSION

This study explored the prevalence of reduced kidney function and kidney function decline in a large, urban Chinese primary care population. Results revealed a prevalence of reduced kidney function of 17.9% and a prevalence of kidney function decline of 19.3%. The prevalence of rapid eGFR decline was 22.8%. Female sex, older age, hypertension, overweight, obesity, diabetes, LVH and dyslipidemia were independent predictors of reduced kidney function. Moreover, older age and a reduced kidney function at baseline were independent predictors of kidney function decline.

Prevalence of reduced kidney function and kidney function decline

The prevalence of reduced kidney function that we found was similar to the 12-23% reported in previous studies in the elderly Chinese population based on health check-up data [15-17]. Our study population was relatively old (69.4±10.7 years). For other countries, the prevalence of reduced kidney function in older people was reported to be 37.1% to 61.7% (Germany; age>70 years old) [26], 19.6% (Brazil; aged ≥60 years) [27] and 11.2% (Australia; mean age of 62 years old) [28]. These discrepancies found may partially be explained by differences in the equations to estimate GFR [26], characteristics of the populations and the setting. Our study was conducted in a primary care setting, while other studies were conducted in community settings; patients could suffer from a chronic illness. This could also explain why we found a higher prevalence of kidney function decline and rapid eGFR decline compared to a previous Chinese community-based population study reporting normal kidney function at baseline [18]. Additionally, the prevalence of rapid eGFR decline in our study was higher than the reported 16% in a community-based cohort of ambulatory elderly individuals in the United States [29]. This could also be explained by the fact that we included data of both participants with and without reduced kidney function at baseline; people with reduced kidney function at baseline would more likely have kidney function decline. Also, the disparity in quality of and access to health care between areas in China could lead to the higher prevalence of kidney function decline in our study. For instance, the previous study was conducted in Beijing with better health care resources than our study setting [18].

Factors associated with reduced kidney function and kidney function decline

We found that diabetes was independently associated with reduced kidney function, which is consistent with a previous study [30]**.** The Global Burden of Disease study suggested that diabetes affects 6.6% of the overall (all-age) Chinese population [31]. Moreover, LVH was revealed as a risk factor for reduced kidney function, which corroborates previous findings [9]. Notably, hypertension, which is a key risk factor of LVH [32], was associated with a lower risk of reduced kidney function in the current study. This could be explained by the use of antihypertensive medications in patients with reduced kidney function in our population. People with reduced kidney function may have been undertreated for CKD and also already treated for hypertension. In the past twenty years, a noteworthy increase in the prevalence of hypertension in the Chinese population has occurred; hypertension affects nearly 23.2% of Chinese adults [33]. Future studies with information on participants' medication use are needed to explore this question further.

Female sex was shown as a risk factor for reduced kidney function, which corroborates previous findings [7]. However, in contrast, other studies indicated that being male is an independent risk factor for reduced kidney function [34]. Future studies can clarify the association between gender difference and reduced kidney function by considering lifestyle differences, such as dietary protein intake, salt, smoking and alcohol intake [35]. Additionally, overweight and obesity were associated with an increased risk of reduced kidney function in our study. Previous data also linked overweight and obesity to reduced kidney function [30, 36] and CKD progression [37]. Overweight and obesity are widely prevalent and are major public health concerns [38, 39].

Previous studies suggested that dyslipidemia mostly develops along with kidney function decline in patients with CKD, even in the early stages. It is also the major risk factor for CVD in patients with CKD [40]. In our study, the prevalence of dyslipidemia was 32.5%, which is similar to a previous survey [36]. We also demonstrated that dyslipidemia was associated with reduced kidney function. Thompson *et al*. found that reduced kidney function was independently associated with lower concentrations of HDL cholesterol and higher concentrations of triglycerides in an Australian population [25]. Similarly, in our study, the proportion of low HDL cholesterol was higher in participants with reduced kidney function than in participants without reduced kidney function. However, the proportion of high fasting triglyceride was lower in participants with reduced kidney function than in participants without reduced kidney function. This could be explained by the use of anti-dyslipidemia medications in patients with reduced kidney function in our population. Nevertheless, the high proportion of high fasting triglyceride still deserves medical attention due to its notable consequences.

Strengths and limitations

Our study has several strengths. To our knowledge, this study is the first primary care population-based study in China to examine the prevalence of kidney function decline and rapid eGFR decline. Also, our study has a large sample size and conducts analyses based on real-world data.

Nevertheless, several limitations should be noted. First, as our study focused on people with health check-up records, information concerning urine tests (e.g. data of albuminuria), the usage of medications such as anti-hypertensive, anti-diabetic and anti-dyslipidemia drugs, self-reported history such as smoking and alcohol use of people and socioeconomic status were not available. Secondly, as participants aged 65 years or older had one free annual health check-up, the entire study population was relatively old. Therefore, the prevalence of reduced kidney function and kidney function decline can be overestimated. Also, these findings may not generalize to the younger population. Third, the serum creatinine measurement was available for 18273 (26.3%) of 69473 people and the follow-up data were available for 3314 (18%) of 18273 people. The related reasons for the lack of data were unknown and could influence the results. For instance, patients with more severe kidney impairment may go for health check-ups more frequently. A prospective cohort study can be conducted for further exploration.

Implications for future research initiatives

To reduce the substantial burden of CKD in the Chinese primary care population, an effective prevention and treatment health care system is needed. For instance, three-level prevention and treatment programs are being developed in Chinese settings [41]. These programs often include primary prevention and treatment, which focuses on targeted screening to achieve early detection of CKD in at-risk groups (e.g. people with diabetes); secondary prevention and treatment, which focuses on the referral of those identified as pre-existing CKD to community hospitals and aims to slow disease progression; tertiary prevention and treatment, which aims to avoid or delay dialysis or kidney transplantation for patients with advanced CKD.

To enhance the development of three-level prevention and treatment system in Chinese settings, we suggest the following initiatives. First, we advise future researchers to implement (online) training and education such as e-learning on CKD prevention and treatment to increase public and health care professional awareness about CKD and its risk factors. Also, considering the risk factors of reduced kidney function are mostly related to lifestyle-related factors such as overweight, lifestyle interventions are needed to support individuals' self-management and improve their health behaviors. As there is an enormous shortage of healthcare professionals in China [42], electronic health (eHealth)-based lifestyle interventions are more accessible and widely used [43]. Second, to support the referral of patients with kidney impairment to a nephrologist in a secondary or tertiary hospital, national guidelines should be developed for medical specialists such as the referral criteria adopted in the Netherlands [44]. Also, an improved primary healthcare system supporting the implementation of integrated approaches can help manage the increasing burden of CKD [45], for instance, the Innovative Care for Chronic Conditions (ICCC) proposed by the World Health Organization (WHO) [46].

CONCLUSIONS

The high prevalence of reduced kidney function and kidney function decline indicates that CKD is a severe public health problem in China. Female sex, older age, hypertension, overweight, obesity, diabetes, LVH and dyslipidemia were independent predictors of reduced kidney function, and older age, a reduced kidney function at baseline to kidney function decline. To reduce the substantial CVD risk and CKD burden in Chinese primary care populations, three-level preventive and treatment programs need to be developed and enhanced. Important strategies would include an (online) education and training program to promote awareness of CKD, widely and accessible (eHealth-based) lifestyle interventions, national guidelines for referral of identified patients to a nephrologist and improving the primary healthcare systems to support the implementation of integrated approaches.

Authors' contributions

HS led the conception and design of this study and is the main contributor in writing this manuscript. HS and WW participated in data collection and analysis. WW, RK, PB, XC, EB, XL and NC contributed to the conception and design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

Not applicable

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Additional file 1. Factors associated with reduced kidney function.

Analysis	Univariable		Model 1		Model 2	
	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*
Female	2.085(1.918-2.266)	<0.001	2.185(2.008-2.377)	<0.001	2.171(2.140-2.203)	<0.001
Age (per year increase)	1.038(1.034-1.042)	<0.001	1.040(1.036-1.045)	<0.001	1.070(1.067-1.074)	<0.001
Hypertension	0.889(0.804-0.983)	0.022			1.369(1.109-1.689)	0.003
Body mass index						
-Healthy weight (BMI, 18.5-23.9 kg/m^2)	Reference				Reference	
-Underweight (BMI<18.5 kg/m^2)	0.825(0.572-1.191)	0.305			0.933(0.578-1.507)	0.778
-Overweight (BMI, 24-27.9 kg/m^2)	1.202(1.106-1.306)	<0.001			1.139(1.005-1.289)	0.041
-Obesity (BMI≥28 kg/m2)	1.833(1.635-2.056)	<0.001			1.508(1.193-1.905)	0.001
Diabetes (FBG≥7 mmol/L)	1.361(1.225-1.511)	<0.001			1.299(1.042-1.618)	0.020
Left ventricular hypertrophy	1.726(1.224-2.435)	0.002			2.702(1.723-4.238)	<0.001
Total cholesterol>6.22 mmol/L	1.628(1.447-1.833)	<0.001			1.279(0.963-1.700)	0.089
Fasting triglyceride>2.26 mmol/L	0.845(0.759-0.941)	0.002			0.730(0.577-0.922)	0.008
Serum LDL cholesterol>4.14 mmol/L	3.423(3.010-3.893)	<0.001			1.224(0.864-1.734)	0.254
Serum HDL cholesterol<1.04 mmol/L	1.274(1.072-1.514)	0.006			1.793(1.414-2.273)	<0.001
No. of CVD risk factors						
-0	Reference				Reference	
-1-2	1.226(1.092-1.377)	0.001			0.915(0.714-1.173)	0.483
-≥3	1.439(1.168-1.773)	0.001			0.689(0.391-1.214)	0.197

The total number of CVD risk factors per patient was calculated based on the presence of the following: obesity, hypertension, diabetes, abnormal total cholesterol, abnormal fasting triglycerides, abnormal LDL cholesterol, abnormal LDL cholesterol and LVH. Abbreviations: OR: odds ratio; CI: confidence interval; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease. Model 1 was adjusted for sex and age; Model 2 adjusted for sex, age, hypertension, body mass index, diabetes and left ventricular hypertrophy, total cholesterol>6.22 mmol/L, fasting triglyceride>2.26 mmol/L, serum LDL cholesterol>4.14 mmol/L, serum HDL cholesterol<1.04 mmol/L and no. of CVD risk factors.

Additional file 2. Factors associated with kidney function decline.

Analysis	Univariable		Model 1		Model 2	
	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*	OR (95% CI)	*P -value*
Female	0.736(0.618-0.876)	0.001	0.735(0.617-0.875)	0.001	0.848(0.697-1.031)	0.099
Age (per year increase)	0.997(0.987-1.006)	0.477	0.996(0.987-1.006)	0.435	1.013(1.002-1.024)	0.016
Reduced kidney function at baseline	11.834(8.382-16.709)	<0.001			11.193(7.863-15.933)	<0.001
Hypertension	1.244(1.003-1.543)	0.047			1.218(0.875-1.695)	0.241
Body mass index						
-Healthy weight (BMI, 18.5-23.9 kg/m^2)	Reference				Reference	
-Underweight (BMI<18.5 kg/m^2)	1.414(0.738-2.710)	0.297			1.125(0.554-2.286)	0.744
-Overweight (BMI, 24-27.9 kg/m^2)	0.886(0.735-1.069)	0.208			0.910(0.740-1.119)	0.371
-Obesity (BMI≥28 kg/m2)	0.791(0.603-1.039)	0.092			1.174(0.803-1.718)	0.408
Diabetes (FBG≥7 mmol/L)	0.834(0.656-1.060)	0.138			0.997(0.714-1.392)	0.987
Left ventricular hypertrophy	0.833(0.284-2.446)	0.740			0.871(0.276-2.751	0.814
Total cholesterol>6.22 mmol/L	0.868(0.651-1.159)	0.338			1.277(0.849-1.921)	0.239
Fasting triglyceride>2.26 mmol/L	0.998(0.789-1.263)	0.988			1.290(0.904-1.839)	0.160
Serum LDL cholesterol>4.14 mmol/L	0.767(0.424-1.387)	0.379			0.821(0.388-1.739)	0.605
Serum HDL cholesterol<1.04 mmol/L	0.808(0.587-1.112)	0.189			0.926(0.618-1.387)	0.708
No. of CVD risk factors						
-0	Reference				Reference	
-1-2	0.850(0.691-1.045)	0.122			0.727(0.505-1.047)	0.087
-≥3	0.863(0.604-1.234)	0.419			0.606(0.264-1.393)	0.237

The total number of CVD risk factors per patient was calculated based on the presence of the following: obesity, hypertension, diabetes, abnormal total cholesterol, abnormal fasting triglycerides, abnormal LDL cholesterol, abnormal LDL cholesterol and LVH. Abbreviations: OR: odds ratio; CI: confidence interval; BMI: body mass index; FBG: fasting blood-glucose; LDL: low-density lipoprotein; HDL: high-density lipoprotein; CVD: cardiovascular disease Model 1 was adjusted for sex and age; Model 2 adjusted for sex, age, hypertension, body mass index, diabetes and left ventricular hypertrophy, total cholesterol>6.22 mmol/L, fasting triglyceride>2.26 mmol/L, serum LDL cholesterol>4.14 mmol/L, serum HDL cholesterol<1.04 mmol/L and no. of CVD risk factors.

Chapter 4

Development and evaluation of an eHealth self-management intervention for patients with chronic kidney disease in China: protocol for a mixed-method hybrid type 2 trial

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BMC Nephrology 2020;21(1):495.

Abstract

Background

Chronic kidney disease (CKD) is a significant public health concern. In patients with CKD, interventions that support disease self-management have shown to improve health status and quality of life. At the moment, the use of electronic health (eHealth) technology in self-management interventions is becoming more and more popular. Evidence suggests that eHealth-based self-management interventions can improve health-related outcomes of patients with CKD. However, knowledge of the implementation and effectiveness of such interventions in general, and in China in specific, is still limited. This study protocol aims to develop and tailor the evidence-based Dutch 'Medical Dashboard' eHealth self-management intervention for patients suffering from CKD in China and evaluate its implementation process and effectiveness.

Methods

To develop and tailor a Medical Dashboard intervention for the Chinese context, we will use an Intervention Mapping (IM) approach. A literature review and mixed-method study will first be conducted to examine the needs, beliefs, perceptions of patients with CKD and care providers towards disease (self-management) and eHealth (self-management) interventions (IM step 1). Based on the results of step 1, we will specify outcomes, performance objectives, and determinants, select theory-based methods and practical strategies. Knowledge obtained from prior results and insights from stakeholders will be combined to tailor the core interventions components of the 'Medical Dashboard' self-management intervention to the Chinese context (IM step 2-5). Then, an intervention and implementation plan will be developed. Finally, a 9-month hybrid type 2 trial design will be employed to investigate the effectiveness of the intervention using a cluster randomized controlled trial with two parallel arms, and the implementation integrity (fidelity) and determinants of implementation (IM step 6).

Discussions

Our study will result in the delivery of a culturally tailored, standardized eHealth self-management intervention for patients with CKD in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life. Moreover, it will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.

INTRODUCTION

Prevalence and burden of chronic kidney disease

Chronic kidney disease (CKD) poses a significant threat to public health [1–3]. Globally, 698 million individuals are affected by CKD [4]. In China, an estimated 10.8% (119.5 million) of adults suffer from CKD [5]. CKD is defined as abnormalities of kidney structure or function, present for more than 3 months, with severe implications for health [6]. CKD is chronic and categorized into five stages based on the level of glomerular filtration rate (GFR) and albuminuria [6]. Numerous detrimental health outcomes are linked to CKD [7]. Also, CKD increases mortality risk and hospitalization rates, and negatively impacts the quality of life [7–9]. Additionally, health-related and societal costs of CKD are considerable and constitute a substantial economic burden [10–12].

Self-management and eHealth interventions for CKD

Interventions that support disease self-management (further referred to as 'self-management interventions') can have a significant impact on the health and quality of life of patients suffering from chronic conditions in general [13], and patients with CKD in specific [14-16]. Self-management support is often defined as "*[……] improving chronic illness outcomes consisting of patient-centered attributes (involving patients as partners; [……]), provider attributes (possessing adequate knowledge, skills, attitudes in providing care), and organizational attributes (putting an organized system of care in place, having multidisciplinary team approach, using tangible and social support)*" [17].

In the last decade, the use of electronic health (eHealth) technology in self-management interventions has become more and more popular. EHealth technology can facilitate remote patient-provider communication and exchange of (health) data and has the potential to increase healthcare accessibility and efficiency [18]. EHealth-based self-management interventions have been shown to improve health-related outcomes, such as blood pressure (BP) control and medication adherence [19, 20], and found to be feasible and acceptable for patients with CKD and care professionals [19]. Hence, the use of eHealth self-management interventions for patients with CKD has become increasingly popular. Knowledge of the implementation and effectivity of such interventions in China and other developing countries is, however, still lacking [21].

Medical dashboard

Researchers from the Leiden University Medical Center (LUMC) developed 'Medical Dashboard', an eHealth intervention to help support and involve patients with CKD in their disease self-management. This platform is used in the Outpatient Clinic Kidney

Transplant of the LUMC since February 2016. Via Medical Dashboard, patients can monitor their health from home (e.g. BP, weight), and can exchange health data with their care professionals. Moreover, during consultations in the outpatient clinic, care professionals and patients can also use Medical Dashboard to set personal health goals such as BP control and nutrition management (e.g. energy). In a randomized controlled trial (RCT), the use of "Medical Dashboard" has been shown to improve patients' adherence to sodium restriction intake and BP control [14]. Also, patients reported being highly satisfied with the online disease management system used in the platform [22]. All core intervention components of 'Medical Dashboard' and their supporting evidence base are presented in Additional file 1 (https://www.ncbi.nlm.nih.gov/ pmc/articles/ PMC7678219/).

Opportunities for eHealth interventions in China

There is significant support and momentum for the implementation of eHealth based self-management interventions in China. China had 731 million internet users (penetration rate 53%) and 1.3 billion mobile phone users (penetration rate of 90%) in 2016, and this number is still growing [23-26]. Furthermore, policymakers and care experts in China have recently launched the national health strategy 'Healthy China 2030'. This strategy describes eHealth technology as an essential pillar to improve disease self-management as well as the accessibility and cost-effectiveness of care in rural areas. Moreover, it views eHealth technology as the preferred medium to reach one of the main goals: '*enable everyone to be involved in health, share health, and be responsible for health*' [27, 28]. Also, the prevalence rate and severe adverse health outcomes of CKD have put it high on the public health agenda in China.

Study aims and research methods

In conclusion, eHealth self-management interventions have the potential to fundamentally improve the quality of life and health outcomes of patients suffering from CKD in China. The Medical Dashboard based self-management intervention has been researched extensively and proven effective. Also, our research team has a close relationship with its developers and is therefore able to amend and upscale the intervention globally. Therefore, we aim to tailor the evidence-based Dutch intervention 'Medical Dashboard' to the Chinese context and evaluate its implementation process and effectiveness. To this end, we will use an intervention mapping (IM) approach comprising six steps: (1) a needs assessment, (2) preparation of change objectives matrices, (3) selection of theory-informed intervention methods and strategies, (4) development of a tailored 'Medical Dashboard' based intervention plan, (5) development of an implementation - and (6) evaluation plan.

In correspondence with the steps of IM [29], we aim to:

- Phase 1: Needs, beliefs and perceptions (Step 1 of IM)

Examine the needs, beliefs, perceptions of patients with CKD and care providers towards disease self-management and eHealth interventions;

- Phase 2: Intervention and implementation development & planning (Step 2-5 of IM)

Tailor the core components of the 'Medical Dashboard' self-management intervention for patients with CKD to the Chinese context;

- Phase 3: Intervention evaluation (Step 6 of IM)

Employ a hybrid type 2 trial to:

- Evaluate the effectiveness of the intervention using a cluster RCT with two parallel arms;
- Evaluate implementation integrity (fidelity) and determinants of implementation.

METHODS

The study has been approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (reference number 2019-KY-52).

Study setting

All study phases are (to be) conducted in the First Affiliated Hospital of Zhengzhou University in the Henan province in China. Henan is one of the biggest provinces of China, and it accounts for 9% of the rural Chinese population. An estimated 16.4% (12 million) of adults suffer from CKD in rural areas in Henan [30]. The Department of Nephrology of the First Affiliated Hospital of Zhengzhou University has five sub-units with approximately 276 beds; more than 60,000 patients with CKD visit the Outpatient Clinic of Department of Nephrology each year.

Overview of study design

An overview of the study flow following the six steps of IM is displayed in Table 1.

Phase 1

Aim

Preliminary evidence suggests that both patients' and care providers' needs, beliefs (i.e. an idea or principle judged to be true) and perceptions (i.e. the organized cognitive representations that individuals have about a subject) of disease (self-management) can influence their display of health behaviors and uptake of (self-management) interventions [31-34]. Therefore, following step 1 of IM, we will first conduct a needs assessment and examine the needs, beliefs, perceptions of patients with CKD and care providers towards disease (self-management) and the use of eHealth interventions.

Table 1. Overview of study phases.

Phase	IM steps	Activities
I	Step 1 Conduct needs assessment	• Establish an intervention monitoring group • Perform a systematic literature review • Conduct a mixed-methods study into needs, beliefs & perceptions of patients with chronic kidney disease and care providers toward chronic kidney disease (self-management) and the use of eHealth (self-management) interventions
II	Step 2 Identify outcomes, performance objectives, and determinants	• Formulate program outcomes • Specify performance objectives • Specify determinants of change • Map the performance objectives to the determinants and create a matrix of change objectives
	Step 3 Select theory-based methods and practical strategies	• Review potentially relevant theoretical methods • Match each determinant to the relevant method(s) • Translate methods into practical strategies to target each determinant • Monitoring group reaches consensus on methods and practical strategies
	Step 4 Develop a tailored 'Medical Dashboard' based intervention (plan)	• Develop an intervention plan by tailoring the core components of the Dutch Medical Dashboard to the Chinese context • Member check with the target population
	Step 5 Develop an adoption- and implementation plan	• Identify potential adopters and implementers • Specify program use outcomes and performance objectives • Specify determinants of change • Map the performance objectives to the determinants and create a matrix of change objectives • Design a plan for adoption and implementation • Member check with the target population
III	Step 6 Develop an intervention evaluation plan	• Specify the two-arm, hybrid 2 trial design and: -Develop the effectiveness evaluation plan -Develop the implementation evaluation plan

Design

Intervention monitoring group

First, an intervention monitoring group including both Dutch and Chinese experts and other key stakeholders will be established. This group will consist of two researchers, one nephrologist, one nurse in CKD practice, one implementation specialist, one primary care clinician, one rehabilitation therapist, one patient with CKD, one patient advisor, and one informal caregiver. The expert group has ample experience with CKD care and the implementation of (eHealth) self-management interventions. The intervention monitoring group will meet monthly throughout all IM steps to discuss progress and the execution of major deliverables such as the needs assessment (e.g. program goals), intervention development (e.g. intervention content, delivery strategies), and evaluation planning (e.g. inclusion, outcome choice, analysis).

Literature review

A scoping literature review will be conducted to identify relevant evidence on needs toward disease management of patients with CKD and care providers. The search strategy is already developed in collaboration with a certified librarian (see Additional file 2: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7678219/).

Mixed-method study

Research methodology

We will conduct a mixed-method study to gain insight into the needs, beliefs, perceptions of patients with CKD, and care providers towards disease (self-management) and the use of eHealth (self-management) interventions. This study will include face to face interviews, focus group discussions, observations, and survey research. Methods will build on an adapted version of the theoretical framework on beliefs and perceptions towards chronic lung disease used in FRESH AIR (Brakema et al., submitted). This adapted framework combines the Health Belief Model [35] and the Theory of Planned Behavior [36] and focuses on individuals' beliefs and perceptions as well as the sociocultural context in which the individual resides (see Figure 1).

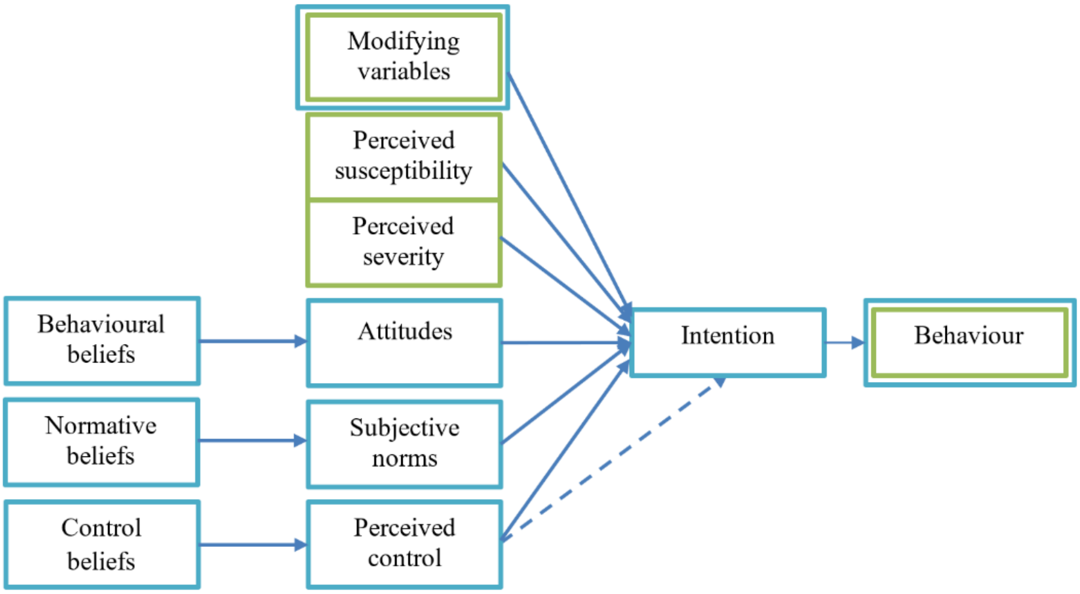

Figure 1. Adapted version of the theoretical framework of Brakema et al (submitted). A combination of concepts of the Health Beliefs Model (green) and the Theory of Planned Behavior (blue).

We will explore patients' and care providers': (1) beliefs and perceptions towards CKD and disease self-management, (2) needs towards CKD self-management, and (3) needs, beliefs, perceptions towards the use of eHealth interventions in disease self-management. The survey will consist of three validated measures: (1) 'The Brief Illness Perception Questionnaire' (BIPQ) [37], (2) 'Chronic Kidney Disease Self-management instrument' (CKD-SM) [38], and (3) 'Chinese eHealth Literacy Scale' (C-eHEALS) [39]. Each questionnaire will be tested on usability, feasibility, and acceptability by ten volunteers patients before they are to be used on a larger scale. If any issues arise, the questionnaires will be adapted accordingly, for instance, by reformulating specific questions.

Sample size calculation

For the qualitative part, following principles of "purposive and convenience sampling" [40], the inclusion of participants will be based on opportunity, willingness to participate, and creation of diversity (e.g. different stages of CKD, age, gender) in our sample. We will also use snowball sampling [41], in which participants will be asked if they know any other individuals who could participate in the study. As there are no defined rules for calculating sample size in qualitative studies [42], target numbers are set for the data collection based on previous literature and our experience in previous studies (Table 2). The definitive sample size for all qualitative research elements will be determined based on when data saturation is achieved, which is the point when no new or relevant information is identified through the preliminary analysis of the data [43]. For the quantitative part, as a rule of thumb, the sample size should be 5-10 times the number of items in the questionnaires [44]. Therefore, we aim to recruit at least 230 patients in the quantitative survey (Table 2).

Table 2. Sample size calculation in a mixed-method study.

Method	Sampling	Participants	Sample (range between records)
Face to face interview	Purposive, Convenience	Care providers Patients	10-15 care providers minimum 10-15 patients minimum
Focus group discussion	Purposive, Convenience	Patients	2-3 groups of 8-10 patients in total
Observation	Purposive, Convenience	Care providers Patients	10-15 observations minimum
Survey	Randomly	Patients	230 patients minimum

Study population

The eligibility criteria of participants are detailed in Table 3. Approximately 200 care providers, of which 60 are nephrologists, in the Department of Nephrology of the First Affiliated Hospital of Zhengzhou University are available for potential recruitment. The methods to be used differ between patients and care providers following the relevant group- and context characteristics (see details in Table 4). For instance, focus groups cannot be held with care providers as they (1) cannot be of duty all at the same time, and (2) work with a tight schedule, and finding a time slot that suits all care providers is very difficult. Moreover, we feel that patients with CKD would be comfortable discussing their needs towards eHealth self-management interventions in a focus group setting, but not their needs and beliefs towards their disease in general. Hence, we will plan to discuss this topic in face-to-face interviews. More details on the methods use and relevant research materials used are presented in Additional file 3 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7678219/).

Table 3. Eligibility criteria for patients with chronic kidney disease and care providers.

Category	Participant eligibility criteria
Inclusion criteria	• Patients: (1) aged over 18 years old; (2) a diagnosis of chronic kidney disease (CKD) with markers of kidney damage or a glomerular filtration rate of less than 60 ml/min/1.73m^2 persisting for ≥3 months based on Kidney Disease Improving Global Outcomes (KDIGO) guidelines [6]; (3) all CKD stages (stage 1-5) following the KDIGO staging of CKD [6]; (4) Chinese speaking. • Health care providers (1) who work in the Department of Nephrology of the First Affiliated Hospital of Zhengzhou University (2) are able to implement the intervention in their daily practice
Exclusion criteria	• Individuals unable to provide written informed consent and use electronic application due to physical disabilities such as eyesight problems or mental disabilities such as psychosis, personality disorders or schizophrenia (final decision for exclusion will be made by the treating physician) • Individuals unable to write or read.

Table 4. Field methods used for topics.

Topic	**Methods**			
	Face to face interview	Focus group discussion	Observation	Survey
Care providers				
- Beliefs, perceptions, toward chronic kidney disease and self-management	X		X	
- Needs toward chronic kidney disease self-management	X		X	
- Needs, beliefs, perceptions toward eHealth self-management interventions	X		X	
Patients				
- Beliefs, perceptions, toward chronic kidney disease and self-management	X		X	X
- Needs toward chronic kidney disease self-management	X		X	X
- Needs, beliefs, perceptions toward eHealth self-management interventions	X	X	X	X

Phase 2

Aim

Following step 2-5 of IM, we aim to tailor the core interventions components of the 'Medical Dashboard' self-management intervention to the Chinese context following the results of the needs assessment performed in Phase I.

Design

All the IM concepts used in the steps below are operationalized and further detailed in Table 5 and Figure 2.

Table 5. The concepts from Intervention Mapping step 2-5.

Intervention Mapping concepts	Definition in Bartholomew LK et al. [29]
Step 2	
Program outcome	Desired changes in the behavior and the environmental conditions
Performance objective	The required actions to accomplish the change in the behavioral and environmental outcomes
Determinant	Factors that are associated with the performance of behavior
Change objective	Specific goals stating what should change at the determinants for program outcomes in different level
Step 3	
Theoretical method	General technique or process for influencing changes in the determinants of behaviors and environmental conditions
Practical strategy	A specific technique for the practical use of theoretical methods in ways that fit with the target group and the context in which the intervention will be conducted
Step 4	
Intervention plan	A plan detailing intervention scope, sequence including delivery channels, themes, and list of intervention materials needed
Step 5	
Implementation plan	A plan detailing how intervention adoption and implementation can be supported and maintained over time.

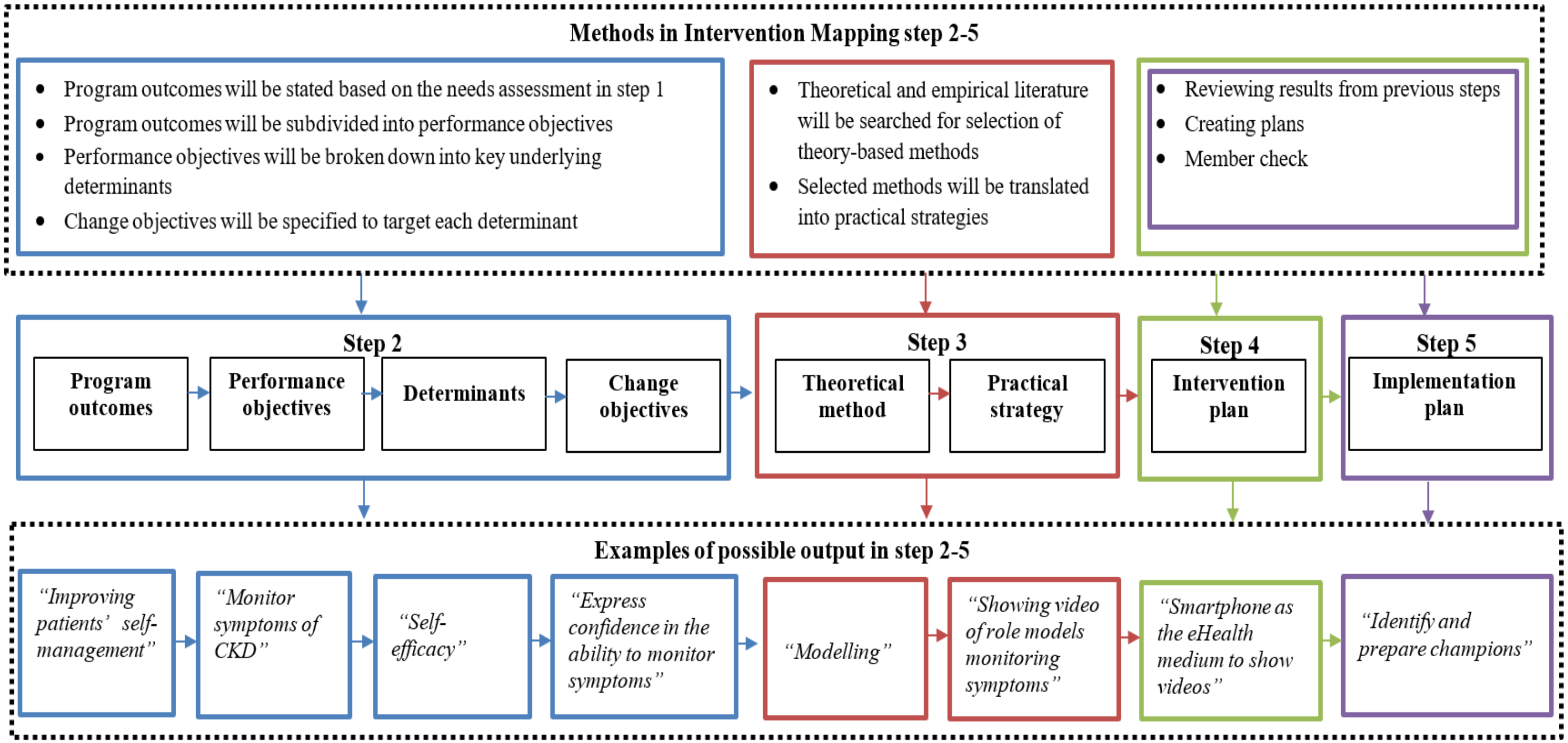

Figure 2. Methods and examples of the possible output of Intervention Mapping step 2-5. Step 2 (blue), step 3(red), step 4(green), step 5(purple).

Step 2: Preparing matrices of change objectives

First, we will formulate *program outcomes* [29] on all levels as defined in the socio-ecological model [45]. This model will help us to understand the complex interplay between individual, interpersonal, community, and societal outcomes. Second, we will subdivide program outcomes into *performance objectives* [29]. Third, as each performance objective can only be reached if matching behavioral determinants are addressed, we will break each performance objective down into *key underlying determinants* [29]. We will use the Theoretical Domains Framework (TDF) to support the identification and selection of relevant determinants of behavior [46]. Two researchers will independently identify the determinants, and discrepancies will be resolved through discussions. Also, the intervention monitoring group will evaluate the determinants selected based on relevance and changeability, using the four possible consensus-based recommendation levels proposed by Michie et al [46]. Finally, based on the determinants identified, we will specify *change objectives* [29].

Step 3: Selecting theory-informed intervention methods and practical strategies

We will first review the literature and identify relevant *theoretical methods* that can potentially induce a change in the determinants identified in step 2 [29]. Second, we will match the selected methods with specific change objectives. Third, the selected methods will be translated into practical strategies to target each determinant. Finally, the intervention monitoring group will rank the practical strategies per method [46] and ensure that these methods and practical strategies match with the program goals.

Step 4: Develop a tailored 'Medical Dashboard' based intervention (plan)

First, we will review the results of the needs assessment, the initial program's logic model of change, and discuss intervention objectives, theoretical methods, and practical strategies for each level (e.g. individual, organization) specified in step 1-3. Second, the intervention monitoring group will have a meeting to amend, and if necessary, adapt the Medical Dashboard intervention. Only surface level adaptations will be made [47], such as the tailoring of educational content based on the results of the needs assessment, or by extending the intervention delivery medium to tablets or personal computers (listed in Additional file 1: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7678219/). To ensure the effectiveness of the Medical Dashboard based self-management intervention, we will not change the core self-management intervention components of Medical Dashboard that underline its effectivity, such as the provision of information support or self-monitoring. Also, the intervention monitoring group will create a plan for developing and testing the new version of the Medical Dashboard. Third, we will recruit five patients and five care providers to discuss the acceptability and feasibility of the intervention plan (member-check). To this end, we will use the 'think aloud' method [48], in which patients and care providers can speak aloud any words in their mind as they read through parts of the intervention plan. The think-aloud research method has been demonstrated to provide valid data on participant thinking and was successfully used in other intervention development studies [49, 50]. Based on the results obtained, further modifications will be made, resulting in a pre-tested version of the intervention plan ready for implementation in practice. The description of the intervention plan will follow the Template for Intervention Description and Replication [51].

Step 5: Develop an adoption and implementation plan

The goal of this step is to write a detailed adoption and implementation plan, containing relevant strategies to optimize intervention delivery and implementation (fidelity). First, we will discuss results obtained from step 1-4 and inventory local resources (e.g. connections with primary care clinics) that may facilitate intervention implementation. Second, based on all results obtained from previous steps and our previous systematic review [21], the intervention monitoring group will have a meeting to pragmatically identify potential adopters and implementers. Also, this group will demonstrate program use outcomes, performance objectives and related determinants of implementation. Third, the intervention monitoring group will design the implementation plan following Figure 3 [52] based on Expert Recommendations for Implementing Change list of strategies [53]. Then, we will use the 'think aloud' method to obtain feedback from patients with CKD and care providers on the implementation plan. Finally, the adoption and implementation plan will be finalized with further modifications.

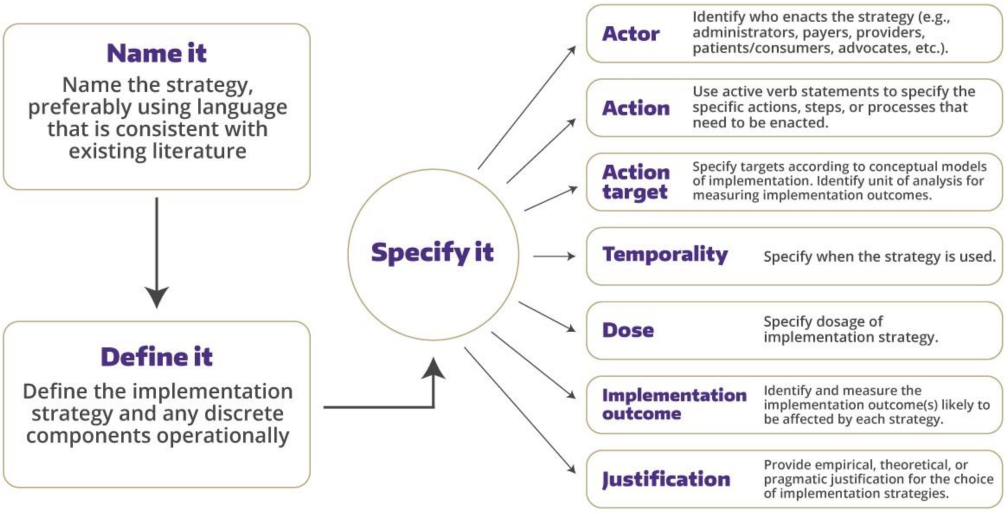

Figure 3. Guidance for specifying implementation strategies of Proctor EK et al. [52].

Phase 3

Aim

Following step 6 of IM, we will establish an intervention evaluation plan. Our evaluation will follow a hybrid type 2 trial design, comprising of (1) a cluster RCT with two parallel arms to study effectiveness, and (2) a process evaluation to evaluate implementation integrity (fidelity) and determinants of implementation.

Design

This study will consist of a 9-month, cluster RCT with two parallel arms, integrated into a hybrid type 2 trial [54]. The trial design and corresponding study elements are detailed in Figure 4. We selected an intervention duration of 9 months, as previous literature provides support that this intervention duration is sufficient to demonstrate the impact on several self-management outcome indicators [55, 56]. The Standard Protocol Items: Recommendations for Interventional Trials 2013 Statement is used to report the RCT protocol [57] (see Additional file 4: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7678219/), and the Standards for Reporting Implementation Studies will be followed for reporting the implementation study [58].

Intervention

Patients with CKD in the comparison group will receive usual care consisting of personalized in- and outpatient treatment based on symptoms experienced and disease severity, as outlined in the Kidney Disease Improving Global Outcomes (KDIGO) guidelines [6]. Patients with CKD in the intervention group will receive the usual care plus the culturally tailored 'Medical Dashboard' based self-management intervention for 9 months. Also, care providers in the intervention arm will implement the usual care plus the culturally tailored 'Medical Dashboard' based self-management intervention for 9 months. Those who are in the comparison group will implement the usual care. Before the start of the intervention, patients with CKD and care providers will receive a face-to-face training session on the use of Medical Dashboard. To avoid contamination, Medical Dashboard will only be made accessible for participants in the intervention group via a secure password-protected registration process.

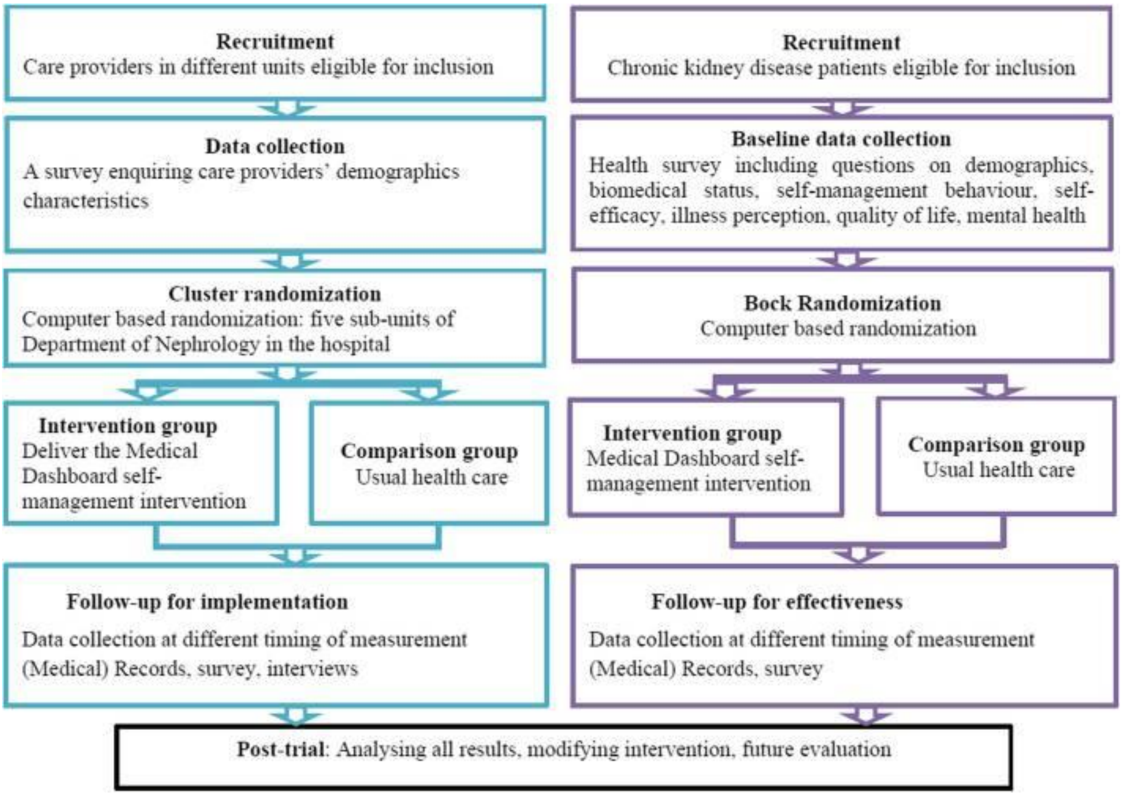

Figure 4. Study schema.

Study population, recruitment & randomization

Effectiveness; RCT

Patients with CKD and care providers will be recruited from the First Affiliated Hospital of Zhengzhou University. Recruitment strategies, inclusion, and exclusion criteria are identical to those in phase 1 (see Table 3 and Additional file 3: https://www.ncbi.nlm.nih.gov/pmc/ articles/PMC7678219/). We summarize the participant flow through the study in Figure 5. The outcomes for effectiveness are presented in Table 6.

A cluster-randomized trial will be performed. This means that health-care providers within different units of the Department of Nephrology will be randomized to either the intervention arm or the control arm using a computer random number generator. Also, we will use block randomization of patients. A biostatistician blind to the study conditions will randomly allocate patients to the intervention (group 1) or control group (group 2) by using a computer-based block randomization procedure. The number of patients in each condition with pre-determined characteristics (i.e. CKD stage, age, gender) will be predefined, and block sizes of 4 and 6 will be used to ensure equal allocation to the two groups. Only the biostatistician will know the block sizes. Thereafter, researchers and patients will be notified of the allocation. The care providers delivering the intervention cannot be blind to the intervention, but will not collect data or analyze outcomes. Those conducting statistical analyses will be blind to group allocation until the evaluation is completed.

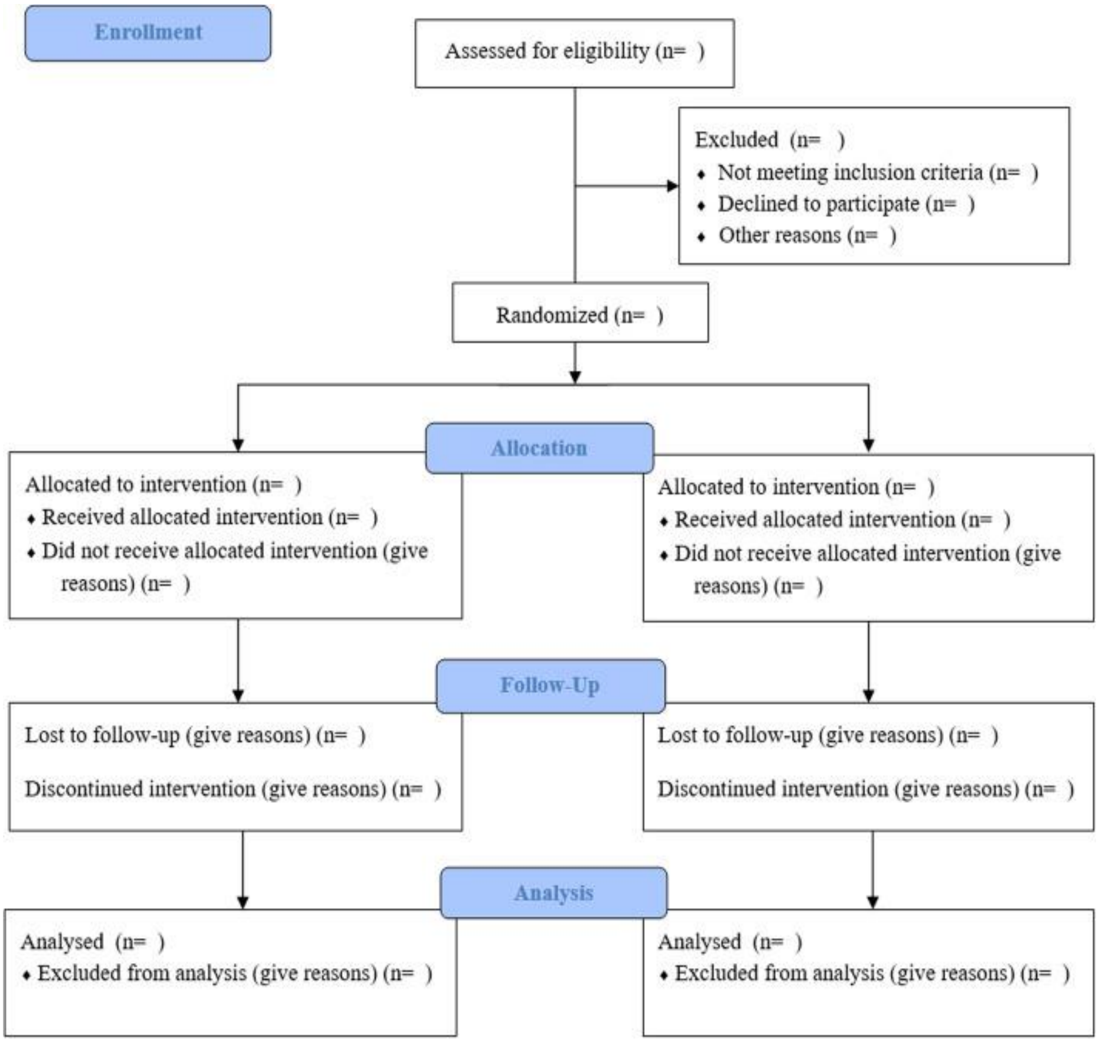

Figure 5. CONSORT flow diagram for our trial.

Implementation study

Patients with CKD, as well as care providers in the intervention group, will participate in the process evaluation to evaluate implementation integrity (fidelity) and determinants of implementation. Implementation outcomes on the patient level as well as care provider level will be evaluated, see the further paragraph about details of outcomes of implementation. A research assistant who will not involve in the RCT study will collect data within process evaluation.

Sample size calculation

Effectiveness; RCT

Based on previous literature [65], we expect the mean CKD self-management score of patients in the intervention group to be approximately 102 ± 20.53 after the 9-month intervention period. When assuming an 80% power and a two-sided significance level of 0.05, the sample size required in each group is 38 patients [66]. Considering a dropout rate of 30% to follow-up, the sample size of patients in this study needs to be 98 patients in total (49 in the intervention and 49 in the comparison group).

Implementation study

All patients with CKD in the intervention group will be invited to complete the survey. Also, patients with CKD and care providers in the intervention group will be invited and interviewed either face to face or by telephone for the process evaluation. We will use "purposive and convenience sampling" to ensure diversity (e.g. CKD stage age, gender) of our sample, especially when there are many patients who would like to join the interview study and choices concerning participation need to be made. If only a few patients indicate that they want to participate in the interview study, we will use snowball sampling [41] to recruit more participants. Via snowball sampling, current participants will be asked if they know any other individuals who could participate in the study. As there are no defined rules for calculating sample size in qualitative studies [42], we expect to conduct a minimum of 10-15 interviews minimum with patients with CKD and care providers per group based on previous literature and our experience in previous studies. The definitive sample size for the interviews will be determined based on when data saturation is achieved through the preliminary analysis of the data [43].

Outcomes measures & data collection

Outcomes for the RCT evaluating the effectiveness

We plan to evaluate:

- patients' physical outcomes including biomedical measures,
- patients' lifestyle and psychosocial functioning including self-efficacy, perceptions about CKD, quality of life, anxiety and depression status,
- hospital admission, health care utilization, and cost-benefit

A trained research assistant will conduct data collection, and the intervention monitoring group will supervise the data collection process. We will invite participants in both the intervention and comparison group to visit the Department of Nephrology at the First Affiliated Hospital of Zhengzhou University for data collection at baseline (T0), 3 months (T1), 6 months (T2) and 9 months (T3) post-randomization. At baseline, we will collect demographic data, including age, race, income, education, marital status, work type of participants. To avoid dropping out of participants, if participants cannot come to the hospital, data will then be collected via telephone interview. Table 6 provides details on the proposed outcome measures and timing of the measures. The operationalization of outcomes and descriptions of the measurement tools used are detailed in Additional file 5 (https://www.ncbi.nlm.nih.gov/pmc/ articles/PMC7678219/).

Outcomes for implementation integrity (fidelity), and determinants of implementation

The process evaluation will be based on the RE-AIM framework [67]. The RE-AIM model is used to comprehensively measure the public health impact of research conducted in real-world settings [67]. Four dimensions (with the *Effectiveness* domain being applicable above)—Reach *(refers to the proportion of patients with CKD and care providers reached by our program)*, Adoption *(refers to the proportion of participants who use our intervention)*, Implementation *(refer to completion as well as fidelity to the protocol)*, and Maintenance will be used to evaluate the implementation only in the intervention group. We will collect the implementation outcome measurements throughout the 9-month trial. The outcome measures for each dimension of the RE-AIM model are as described in Table 7.

We will use the Measurement Instrument for Determinants of Innovations questionnaire [68, 69] to evaluate the determinants of implementation. Also, individual interviews with stakeholders (e.g. patients, care providers) will be conducted to learn more about the usability and feasibility of Medical Dashboard, its potential for wide-scale implementation, and barriers and facilitators to implementation. We will categorize the determinants identified from this mixed-method study according to Fleuren Framework [70].

Table 6. Effectiveness outcomes and timing of measurements.

Outcome	Outcome Indicators	Measures	Tools	Sources	Timing of measures T0[a]	T1[b]	T2[c]	T3[d]
Primary Outcome								
	Self-management behavior	Survey	Chronic Kidney Disease Self-Management instrument [38, 56]	Patient	X	X	X	X
Secondary outcome								
	Biomedical status	Clinical records	Blood pressure, Bodyweight, Glomerular filtration rate, Serum albumin, Length, Serum calcium, Serum phosphate, Serum hemoglobin, Sodium and protein in 24h urine, albumin/creatinine ratio, Cholesterol, High-density lipoprotein, Low-density lipoprotein, Triglycerides, Hemoglobin A1C, Complications	Patient	X	X	X	X
	Self-efficacy	Survey	Chronic Kidney Disease Self-efficacy scale [56, 59]	Patient	X	X	X	X
	Illness perception	Survey	Brief Illness Perception Questionnaire [37, 60]	Patient	X			X
	Quality of life	Survey	The Kidney Disease Quality of Life 36-item short-form survey [61-63]	Patient	X			X
	Mental health	Survey	Hospital Anxiety and Depression Scale [64]	Patient	X	X		X
	Hospital admission	Survey	The time to first acute hospital admission with an exacerbation of CKD or death due to CKD within nine months after randomization	Patient				X
	Healthcare utilization	Survey	Number of hospitalizations and emergency room visits of patients, primary and secondary care visits	Patient		X		X
	Cost-benefit analysis	Records	All costs delivering the interventions (e.g. materials used in the interventions)	Program, intervention group		X		X
		Records	Medical cost (e.g. cost of treatment, hospitalization rates minored as monetary terms)	Patient		X		X

[a] At baseline
[b] Three months post-randomization
[c] Six months post-randomization
[d] Nine months post-randomization

Table 7. Implementation outcomes (intervention group only).

Outcome	Outcome Indicators	Measures	Tools	Sources
Reach				
	Number of patients (eligible, excluded, enrolled)	Records	The proportion of patients eligible to use our intervention program, excluded, invited, and enrolled	Patient
	Number of health care providers (eligible, excluded, enrolled)	Records	The proportion of care professionals eligible to use our intervention program, excluded, invited, and enrolled	Care provider
	Characteristics of participating patients	Records	Comparing participating patients to the target population on key clinical characteristics (e.g. disease stage)	Patient
	Qualitative assessment-reach	Interview	The barriers/facilitators to study participation	Patient
Adoption				
	Characteristics of participating care providers	Records	Comparing participating care providers to the target population on key characteristics (e.g. work type)	Care provider
	Use of program	Records	Frequency of materials or Medical Dashboard used	Patient, care provider
	Qualitative assessment-adoption	Interview	The appropriateness, comfort, relative advantage, and credibility of the intervention	Patient, care provider
Implementation				
	Implementation completion	Interview, observation	The implementation completion tasks will be made as a checklist, and the completion of the task and the length of time to finish will be checked.	Patient, care provider
	Acceptability and feasibility of the intervention	Interview	Experiences and perceptions of the intervention	Patients, care provider, research assistant
Maintenance				
	Follow up on the use of Medical Dashboard	Records	The use of intervention to assess long-term maintenance	Records
	Qualitative assessment-maintenance	Interview	Perceptions of the integration of intervention in health facilities	Patient, care provider

Data Analysis

Qualitative data analysis

A Framework Method [71] will be used to guide our qualitative analysis. We will structure the qualitative data in a matrix output formed by rows (cases), columns (codes), and 'cells' (summarized data). We will follow the Consolidated Criteria for Reporting Qualitative Health Research (COREQ) to ensure quality and validity [72]. The preliminary analysis with proposed codes and a data saturation grid [43] will be performed to determine when data saturation is reached. Also, the codes developed, and results of the preliminary analysis will be taken into account when performing Framework Method analysis.

Stage A: Transcribing: All audio-taped interviews will be anonymized and transcribed verbatim in Chinese. Long pauses and interruptions (relevant to the study subject) will be noted within the text. Additionally, all participants' names will be replaced by an ID number. Any names mentioned during the interview will not be transcribed. One researcher will perform transcription, and another will check them to ensure content accuracy.

Stage B: Familiarizatio*n*: Two researchers HS (female, 28 years old, a PhD student in the field of public health and primary care) and WW (female, 23 years old, Master of Science in Nursing) will independently read all transcriptions and make contextual/reflective notes to become familiar with the whole data set.

Stage C: development of an analytical framework& coding: Atlas.ti for Windows version 7.5.18 (Scientific Software development, Berlin) will be used to analyze our data. Our study includes four qualitative research parts. These are research into the (1) needs, beliefs, perceptions toward CKD and self-management (phase 1); (2) needs, beliefs, perceptions toward eHealth self-management interventions in CKD (phase 1); (3) the acceptability and usability of intervention components (phase 3); (4) determinants of implementation of eHealth self-management interventions (phase 3). Therefore, based on prior literature in which specific theoretical frameworks were used for similar research questions [73-77], we will develop four distinct initial coding trees. For the first and second research questions, we will develop two coding trees based on the adapted version of the theoretical framework of Brakema et al., (submitted) and the TDF [78]. The Technology Acceptance Model [79] will be used to develop the coding tree for evaluating the acceptability and usability of intervention components. Also, the Fleuren framework [70] will be used to develop the coding tree for determinants of implementation of eHealth self-management interventions. The second researcher and third researcher will check the coding tree developed and make amendments if necessary. One researcher will then independently code two or three transcripts using the coding tree, and add new codes if the textual abstracts identified do not fit with the existing set of codes. Then, this researcher will meet with the second researcher and discuss the newly added codes. New codes will be added into the coding tree, and if needed, related codes will be grouped into categories. Thus, the process will be repeated until no new codes arise.

The final coding tree will be checked and approved by the second researcher and the third researcher. This coding tree will include codes and categories; all codes and categories will be operationalized, and relevant examples will be provided.

The finalized coding tree will then be applied to each transcript. One researcher will go through each transcript, highlight the meaningful textual abstracts, and assign the appropriate code from the final coding tree. Then, all codes assigned will be verified by the second researcher. All coding differences will be discussed until consensus is reached.

Stage D: Charting data into the framework matrix: Data will be charted into matrices per research question identified by two researchers using Microsoft Excel 2010. The matrix will comprise of one row per participant and one column per code. Interesting or illustrative quotations will be added to the matrices.

Stage E: Interpreting the data: Overarching themes will be generated from codes derived from the data set by reviewing the matrix and making connections within and between participants and codes. Relations, connections, and causality will be further explored and interpreted, and conclusions will be drawn.

As for data derived from observations, all checklists will be digitalized and transported to Microsoft Excel 2010. Also, all written filed notes will be digitalized and will be taken into account to triangulate data collected from other methods.

Quantitative data analysis

All quantitative analyses will be performed using SPSS version 23 (IBM, Armonk, NY, USA). We will enter the quantitative data into Microsoft Excel 2010 and calculate descriptive statistics such as the mean, standard deviation, median, and range of linear variables, and frequencies and percentages of categorical variables.

To gain insight into the needs, beliefs, perceptions of patients with CKD towards disease (self-management) and the use of eHealth interventions in phase 1, we will use the descriptive statistics to describe patients' demographic characteristics, BIPQ scores, CKD-SM score, and C-eHEALS scores. Also, we will conduct secondary analysis using (1) independent *t*-tests for normally distributed continuous variables, (2) Mann–Whitney U-tests for nonnormally distributed variables and (3) Chi-squared or Fisher's exact tests for categorical variables to compare the difference between certain types of different groups of patients with CKD (e.g. age, gender, disease stage) and BIPQ scores, CKD SM score and C-eHEALS scores. *P*-values <0.05 and odds ratios with a 95% confidence interval excluding one will be considered statistically significant.

In phase 3, one of the primary hypothesis is that patients in the intervention group, when compared to the comparison group, will demonstrate (statistically) significant improvement in self-management behavior at 9 months post-randomization. Secondary hypotheses are that the intervention group when compared to patients in the comparison group, will demonstrate (statistically) significant improvement in biomedical status, self-efficacy, illness perception, mental health, quality of life, hospital admission, healthcare utilization and cost-benefit analysis at the timing of measurement. All primary statistical analyses will be conducted using intent-to-treat methods. The primary goal of statistical analyses is to examine and compare trends over time in the primary outcome. We will replicate this analytic approach for other secondary outcomes; secondary analyses will examine trends over time for biomedical status, self-efficacy, illness perception, mental health, quality of life, hospital admission, healthcare utilization, and cost-benefit analysis. We will use longitudinal, mixed-model analyses to test the hypotheses. Exploratory analyses will assess the impact of the intervention on primary and secondary outcomes for patients.

Mixed analysis of literature review, qualitative and quantitative data by triangulation

We will conduct a combined analysis by merging results of all data analysis; from the review, quantitative and qualitative research [80]. In phase 1, the quantitative results and review results will triangulate the qualitative results to gain insight into the perception of disease, self-management behavior, eHealth literacy, and needs towards CKD self-management. To this end, we will develop a thematic matrix [81] that includes participants' characteristics and data derived from surveys and emerging themes from our qualitative results to summarize patients' illness perception, self-management behavior, and eHealth literacy. Also, another thematic matrix will be developed that includes study characteristics of scoping review and data derived from review results and emerging themes from our qualitative results to summarize the needs of patients and care providers towards CKD self-management. These results will be combined to inform the development of 'Medical Dashboard' based intervention (plan) in phase 2. For instance, if the review and qualitative results show that health education is needed to improve CKD self-management behaviors, we will develop the educational intervention components in the future intervention plan. In phase 3, we will use the results collected from the qualitative interviews to help interpret the quantitative results from the trial. Qualitative results will, therefore, be used to expand upon the results of this trial to understand the implementation process as experienced by participants. For instance, the questionnaire of determinants of implementation will be matched with the qualitative research on determinants of implementation.

DISCUSSION

Some research has shown that eHealth based self-management interventions in CKD can help to improve health-related outcomes. However, evidence on the effectiveness of CKD eHealth based self-management interventions is still inconclusive [21]. Thus, our study will gain insights into the development of theoretically based, and target population tailored implementation of eHealth based self-management interventions to improve CKD care. Our study will add knowledge on the implementation research of eHealth self-management interventions in CKD care, with fitting with the needs and priorities expressed by patients and health care professionals. Also, this study will add evidence of the effectiveness of eHealth based self-management interventions on CKD health outcomes.

There are some strengths to our research. First, we will use an innovative hybrid design to concurrently study the effectiveness and implementation of the tailored 'Medical Dashboard' self-management intervention in CKD care. The hybrid designs can test the implementation process by looking inside the so-called "black box" to see what happens in the intervention implementation and how that could affect intervention outcomes [82, 83]. Therefore, hybrid designs can provide the potential to speed the translation of intervention findings into routine practice by optimizing the implementation process [54]. In addition, the triangulation of both quantitative and qualitative results allows researchers to understand the implementation process and intervention effectiveness from multiple perspectives, different types of causal pathways, and multiple types of outcome, thereby strengthening the validity of intervention effects [80, 82]. Second, the robust theory will be used to guide the process of intervention development. The IM method ensures a theory-based approach from the recognition of a need or problem to the identification of a solution and intervention testing. To translate interventions into different contexts (e.g. health care system, population), it is essential to optimize the intervention fit with the needs and priorities expressed by the target population. IM was successfully applied in the development of self-management interventions for osteoarthritis and chronic low back pain [75], and children with CKD [84, 85]. Also, the

RE-AIM framework as utilized in this study provides systematic guidance on how to evaluate the intervention effect on the process and outcome level. A major limitation of this study is that we only perform the study within one hospital in China. Hence, findings may not be immediately generalizable to other health system contexts in China where the access to eHealth technology is (more) limited. Also, the transferability of developed Medical Dashboard self-management intervention to routine clinical practice in primary care may be limited and needs further exploration. Additionally, barriers to the adoption of Medical Dashboard may be technical issues (e.g. connectivity issues) or a low level of eHealth literacy of participants. To address these challenges, we will include intervention components such as the provision of ongoing technical support and eHealth literacy training in the intervention plan.

In conclusion, our study will result in the delivery of a culturally tailored, standardized eHealth self-management intervention for patients with CKD in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life. Also, this study can serve as proof of concept for the use of IM and a hybrid type 2 trial design to evaluate the implementation and effectiveness of eHealth self-management interventions. Moreover, it will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.

Authors' contributions

HS led the conception and design of this study and is the main contributor in writing this manuscript. RK, PB, XS, WW, TZ, ZL, XL and NC contributed to the conception and design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

This study is funded by the China Scholarship Council.

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Chapter 5

Patients' and healthcare professionals' beliefs, perceptions and needs towards chronic kidney disease self-management in China: a qualitative study

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BMJ Open 2021;11(3): e044059

Abstract

Background

Optimizing disease self-management skills can improve health-related outcomes of patients suffering from chronic kidney disease (CKD). Current research on disease self-management has exclusively focused on high-income, Western countries. To support the adaptation and translation of an evidence-based CKD self-management intervention to the Chinese context, we examined the beliefs, perceptions, needs of Chinese patients with CKD and health care providers (HCPs) towards CKD self-management.

Methods

A basic interpretive, cross-sectional qualitative study comprising semistructured interviews and observations was conducted in one major tertiary referral hospital in Henan province, China. A total of 11 adults with a diagnosis of CKD with CKD stages G1–G5 and 10 HCPs who worked in the Department of Nephrology were included in our study. Data collection continued until data saturation was reached. Interviews were audiotaped, transcribed verbatim, and all data were analyzed using a framework approach.

Results

Four themes emerged: (1) CKD illness perceptions, (2) understanding of and motivation towards CKD self-management, (3) current CKD practice and (4) barriers, (anticipated) facilitators and needs towards CKD self-management. Most patients and HCPs solely mentioned medical management of CKD, and self-management was largely unknown or misinterpreted as adherence to medical treatment. Also, the majority of patients only mentioned performing disease-specific acts of control and not, for instance, behaviour for coping with emotional problems. A paternalistic patient–HCP relationship was often present. Finally, the barriers, facilitators and needs towards CKD self-management were frequently related to knowledge and environmental context and resources.

Conclusions

The limited understanding of CKD self-management, as observed, underlines the need for educational efforts on the use and benefits of self-management before intervention implementation. Also, specific characteristics and needs within the Chinese context need to guide the development or tailoring of CKD self-management interventions. Emphasis should be placed on role management and emotional coping skills, while self-management components should be tailored by addressing the existing paternalistic patient–HCP relationship. The use of electronic health innovations can be an essential facilitator for implementation.

INTRODUCTION

Chronic kidney disease (CKD) is a severe public health problem [1, 2]. Globally, 698 million individuals have been affected by CKD [3]. The burden of CKD is high in China, with an estimated prevalence of 10.8% (119.5 million adults) [4]. CKD is characterized by a gradual and irreversible loss of renal function and is categorized in five stages (CKD stages G1-G5) based on the estimated glomerular filtration rate (eGFR) [5]. Patients with CKD often report significant impairment in health-related quality of life [6] and experience adverse health outcomes [7]. Also, CKD imposes a substantial economic burden due to its considerable health-related and societal cost [8].

Disease self-management (hereafter referred to as self-management) is vital to reducing disease burden and to controlling the health care expenditures for patients with chronic disease [9, 10]. As previously noted [11], self-management is composed of three main tasks: medical, emotional, and role management. Hence, self-management is not limited to medical management but also aims to optimize the uptake of new meaningful behaviors or life roles, and it promotes adequate coping disease consequences [11]. Appropriate self-management has the potential to optimize one's ability to perform the cognitive, behavioral, and emotional behavior necessary to maintaining a satisfactory health-related quality of life [12]. Also, for patients with CKD, self-management interventions may improve self-management behaviors [13-15], and disease-specific knowledge [13], health-related quality of life [16] and health outcomes [16, 17], while it may also slow disease progression [9, 18-20]. Despite these reported successes, many existing self-management interventions are prescriptive and deliver information without taking into account the patients' understanding of self-management [21, 22] or the fact that self-management occurs in a social context [23]. Patients' needs for self-management support are not always known or met [24], and there is very little knowledge on how people with CKD would like to receive self-management interventions [25].

Research on CKD self-management interventions has mostly focused on high-income countries, whereas the CKD burden is highest in low-income and middle-income countries [26]. Hence, there is an urgent need for effective interventions that can decrease the CKD burden in countries with the fewest resources. One possible solution is to translate CKD self-management interventions that have been proven to be effective in high-resource settings to low-resource settings. However, applying a 'one-size-fits-all' approach is not sufficient as interventions cannot be simply translated as a whole to a different context. Instead, the target context should be explored along with the beliefs, perceptions and needs of the target population [27]. To optimize chances of successful implementation, this information should then be used to make context-specific adaptations to the intervention and implementation strategies [28].

To adapt and prepare an existing evidence-based CKD self-management intervention for implementation in China, we performed a qualitative study to examine the beliefs, perceptions and needs of patients with CKD and health care professionals (HCPs) towards CKD (self-management) in China.

METHODS

Overview

The knowledge generated from this basic interpretive [29], cross-sectional qualitative study will inform the adaptation and evaluation of a tailored electronic health (eHealth) self-management intervention for patients with CKD in China based on the Dutch Medical Dashboard intervention [17, 30]. Details on the study protocol have been described elsewhere [31].

We followed the Consolidated Criteria for Reporting Qualitative Health Research (see Additional file 1: https://bmjopen.bmj.com/content/11/3/e044059.info) [32].

Study Setting and Participant Selection

This study took place within the First Affiliated Hospital of Zhengzhou University in the Henan province in China. Henan accounts for 9% of the rural Chinese population. An estimated 12 million or 16.4% of all adults in rural areas of Henan suffer from CKD [33]. The Department of Nephrology of the hospital has approximately 276 beds, and more than 60,000 patients with CKD visit the Outpatient Clinic of this department each year.

Previous literature indicates that patients with CKD G1 or G2 report a multitude of symptoms and fairly high disease burden [34, 35]. Therefore, we anticipated that all patients with CKD (regardless of the CKD stage) have a great need for self-management interventions. Individuals eligible for inclusion were: (1) patients with a diagnosis of CKD with CKD stages G1-G5 and (2) HCPs who worked in the Department of Nephrology. Participants needed to be 18 years or older and speak Chinese. We followed the principles of 'purposive and convenience sampling' [36] to capture a diverse sample. Two sampling frames were used. The sampling frame for patients comprised the following variables: CKD stage, gender and age range. The sampling frame of HCPs comprised the variables: work experience, profession, gender and age. Also, we used snowball sampling [37] to identify additional participants, in which current participants were asked if they knew any other individual who could participate in the study. For instance, participant AW knew another patient via WeChat who was severely ill and therefore did not visit the hospital often. This patient had not heard about the study. We asked participant AW to contact this patient and provide information on study participation. The patient then agreed to participate in our study. Study invitation strategies included: provision of flyers and face-to-face verbal invitations for both patients and HCPs and an online invitation for HCPs. All participants provided written informed consent to participation. Also, patients and HCPs received a reimbursement (20 RMB of telephone credit) for their time spent on the study.

Data collection

One researcher (HS, Msc, female) conducted semistructured face-to-face interviews and observations (see Additional file 2: https://bmjopen.bmj.com/content/11/3/e044059.info) between January 2019 to April 2019. The interviewer had no prior contact with participants. The semistructured interview guide and observation forms were developed based on the FRESH AIR (Free Respiratory Evaluation and Smoke-exposure reduction by primary Health cAre Integrated gRoups) study [38], examples of similar studies [39] and research team discussions (see Additional file 3: https://bmjopen.bmj.com/content/11/3/e044059.info). Also, the interview guide was theory-driven as concepts of the Health Belief Model and the Theory of Planned Behavior were used to develop the topic list. A pilot interview was conducted with both a patient and an HCP to evaluate its content, length, and understandability.

The interviewer was trained and had ample experience with qualitative research. To ensure confidentiality and privacy, face-to-face interviews were performed in a private room in the department. Also, the passive participant observations [40] were conducted during patient outpatient clinic follow-up or during routine care visits. The behavior by and conversation between patient and HCP were both observed. The observations were used to triangulate the interview data and to identify potential differences and similarities between what was said to happen when considering self-management behaviors (interviews) and what actually occurred in practice (observations). The sample size for the interviews and observations was not predetermined. Instead, the sample size was determined based on when data saturation was achieved, being the point at which no new or relevant information could be identified through the iterative, preliminary analysis of the data [41]. All interviews were audiotaped digitally. After each interview, the interviewer made field notes detailing the interview setting, atmosphere and participants' non-verbal behaviors. Additionally, we collected demographic and clinical characteristics of the participants from the patient medical records.

Data analysis

A Framework Method [42] was used to guide our qualitative analysis.

Stage A and B: Transcribing and Familiarization

All audio-taped interviews were anonymized and transcribed verbatim. Also, observation forms were digitalized and transported to Microsoft Excel 2010. Names and identifiers were removed to protect participant confidentiality. One researcher performed transcription and another researcher checked transcripts to ensure content accuracy. Before coding, each transcription was read as full text by the researchers in order to become familiar with the data set.

Stage C: Development of an analytical framework and coding

Atlas.ti for Windows 7.5.18 (Scientific Software development, Berlin) was used for data analysis. We built initial coding trees based on the theoretical framework developed in our study protocol and the Theoretical Domains Framework (TDF) [43]. Three transcripts were coded using the initial tree. New codes that emerged were added to the tree. After discussion among the research team, a final coding tree was agreed on. Then, one researcher coded all transcripts and observation forms using the final coding tree. The assigned codes were verified by a second researcher (WW).

Stage D: Charting data into the framework matrix

Data were further reduced by formulating within-cases and cross-cases [44]. Next, data were charted into matrices per research question using Microsoft Excel 2010 and reviewed by all authors. The matrix comprised one row per participant and one column per code.

Stage E: Interpreting the data

Themes were generated from codes derived from the data set by reviewing the matrix and making connections within and between participants and codes. Emergent themes were then organized into major themes and subthemes. All themes were discussed among the research team and modified if needed. Also, the results of participant observation were triangulated with face-to-face interview analysis.

Establishing rigor in the data collection and analysis process

Rigor in data collection and analysis, by ensuring credibility, confirmability, dependability, transferability and authenticity, was achieved in the following ways [45]. Two team members most closely involved in the fieldwork (HS and WW) met frequently to discuss the constancy of the data collection process and (preliminary) analysis. At regular intervals, meetings were held with members of the wider research team with extensive qualitative (RK) and clinical (PB) experience to discuss codes and categories emerging from the analysis. Also, the framework approach to data analysis allowed data to be compared through the formulation of narratives (in-depth focus) and within-case and cross-case comparisons (comparative focus). Additionally, during data analysis, the two fieldwork researchers kept a research diary and made reflective notes.

Reflexivity

The research group was multidisciplinary as it included researchers, clinicians, nurses and academics from both China and the Netherlands. The diverse disciplinary backgrounds, research experiences and positions of the members of this group stimulated the collection and analysis of rich data, as each member held different perspectives, which were shared and debated during research meetings. As the management of CKD is very different in the Netherlands compared with China, all members reflected on their own experiences with CKD (self-) management and how these might have affected the performance of their research tasks. Moreover, during research meetings, all members reflected on the professional lens through which they observed the phenomenon of interest and how this might have impacted their research tasks.

Patient and public involvement

Patients or the public were not involved in the design, or conduct, or reporting, or dissemination plans of our research.

RESULTS

Participant and Interview Characteristics

A total of 21 face-to-face interviews and 26 observations were conducted (tables 1 and 2). Out of 15 approached patients, 11 patients (73%) agreed to participate in the interview study. Out of 11 approached HCPs, 10 (91%) HCPs agreed. Reasons for refusal to participate included a lack of time due to patients' extended waiting time for a physician consultation or intravenous infusion or lack of interest in the research presented. Reasons reported by HCPs included a lack of time due to work obligations (see Additional file 4 for interview characteristics: https://bmjopen.bmj.com/content/11/3/e044059.info). No significant differences were observed between the final sample and those who refused to participate.

Themes

Four major themes emerged for both patients and HCPs. These themes and respective subthemes are described in the following sections with reference to the relevant quotes (see tables 3-4, Additional file 5: https://bmjopen.bmj.com/content/11/3/e044059.info).

Table 1. Characteristics of patients in face-to-face interview.

Characteristics	**Value (N = 11)**
Age, years*	38.9 ± 9.6 (18-53)
Age category (years), n (%)	
18-28	1 (9)
29-39	4 (36)
40-50	4 (36)
51-61	2 (19)
Sex, n (%)	
Male	5 (46)
Female	6 (54)
Marital status, n (%)	
Never married	1 (9)
Married	9 (82)
Divorced	1 (9)
Highest level of education completed, n (%)	
≤Primary school	3 (27)
Middle school	3 (27)
≥High school graduate	5 (46)
Employment status, n (%)	
Employed (full time and part-time)	2 (18)
Not employed	7 (64)
Farming	0 (0)
Student	1 (9)
Retired	1 (9)
Time since CKD diagnosis (years), n (%)	
<1	5 (46)
1-5	3 (27)
>5	3 (27)
Current CKD stage, n (%)	
CKD stages G1-G3	5 (46)
CKD stages G4-G5	6 (54)
Body weight, kg*	56.8±13.2 (35-79)
Serum albumin, g/L*	35.1±3.9 (29.9-41.9)
Hemoglobin, g/L*	105.8±28.5 (53.1-158)
Serum creatinine, ummol/L*	523.6±519.3 (62-1380)
eGFR, ml/min/1.73m^{2}†	13.7 (3.6-92.7)

CKD, chronic kidney disease; eGFR, estimated glomerular filtration rate.

*Mean ± standard deviation (range).

†Median (inter-quartile range).

Complete data available with the exception of the following variables, with data of body weight available for 9 patients (82%), serum creatinine for 8 patients (73%), eGFR for 9 patients (82%).

Table 2. Characteristics of health care professionals.

Characteristics	**Value (N = 10)**
Age, years*	33 ± 6.1 (25-46)
Age category (years), n (%)	
21-30	4 (40)
31-40	5 (50)
41-50	1 (10)
Female sex, n (%)	9 (90)
Job occupation, n (%)	
Nurse	7 (70)
Nephrologist	3 (30)
Marital status, n (%)	
Never married	2 (20)
Married	8 (80)
Highest level of education completed, n (%)	
Bachelor's degree	5 (50)
Master's degree	3 (30)
Doctoral degree	2 (20)
Years of work experience in medical practice, n (%)	
<5	2 (20)
5-10	3 (30)
>10	5 (50)
Years of work experience in nephrology practice, n (%)	
<5	3 (30)
5-10	3 (30)
>10	4 (40)

*Mean ± standard deviation (range).

Table 3. Representative quotations on CKD illness perceptions, understanding of and motivation towards CKD self-management.

Themes and Subthemes	**Representative Quotation**
CKD illness perceptions	
Anticipated concerns on diagnosis	Q1. *[I had] swollen eyes and legs, [I thought] I was just not acclimatized at that time. I have never heard of this disease.* (Patient 7, 29-39y, CKD G4-G5). Q2. *I have not even had a cold before. Why do I get this CKD?* (Patient 3, 40-50y, CKD G4-G5). Q3. *The first is that it is difficult to accept that I am sick. I have a feeling that I would be useless in the rest of my life*. (Patient 5, 29-39y, CKD G1-G3). Q4. *I only have a part-time job. If I have dialysis four times a day, I need to work part-time for [a few] hours, which is equivalent to cutting off the source of the financial resources of my family*. (Patient 9, 51-61y, CKD G4-G5).
Physical consequences	Q5. *Patients are very weak, and the symptoms of fatigue are more prominent*. (HCP6, 29-39y). Q6. *[I had] retching and vomiting. Also, I smell the urea when I breathe out. It is really uncomfortable*. (Patient 10, 40-50y, CKD G4-G5).
Psychosocial consequences	Q7. *Now, I can only stay at home and do not have any contact with the world outside. I am abandoned by the world*. (Patient 8, 40-50y, CKD G1-G3). Q8. *The biggest impact [of CKD] is being unable to work. I can not make money to support my family.* (Patient 5, 29-39y, CKD G1-G3). Q9. *I need to count on my husband to earn money and pay for my costs... If my husband does not need to take care of me, he can make money*. (Patient 10, 40-50y, CKD G4-G5).

Lifestyle consequences	Q10. *The first [influence] is [that I need] to take medicines at home every day and stay at home*. (Patient 8, 40-50y, CKD G1-G3). Q11. *Because I need to conduct dialysis several times every day, I can not go anywhere*. (Patient 7, 29-39y, CKD G4-G5).
Understanding of and motivation towards CKD SM	
Understanding of CKD SM	
Patients' responses towards the understanding of CKD SM	Q12. *The doctor has prescribed a way how to do it. I should try my best to do it. I should do what the doctor says and pay attention to what precautions doctors mentioned.* (Patient 7, 29-39y, CKD G4-G5). Q13. *Doctors said that I can not exercise too much, eat spicy [food], and should eat less salt.* (Patient 2, 18-28y, CKD G1-G3). Q14. *I hear from nurses that I need to take care of self-protection, pay attention to the sanitation of dialysis environment.* (Patient 1, 40-50y, CKD G4-G5).
HCPs' responses towards the understanding of CKD SM	Q15. *After the patient is discharged from the hospital, he can manage the disease himself, for example, his adherence to taking medication, diet [restrictions], exercise, and regular follow up.* (HCP3, 18-28y). Q16. *Patients [with CKD] must have the knowledge of this disease at first...what disease stage he is in now...then they can pay attention to... improving their lifestyles...* (HCP5, 29-39y).
Motivation towards CKD SM	Q17. *I stayed up late. It can be a cause and risk of the CKD. So I have to avoid it...I should have restrictions according to what doctors told me, for example, eating.* (Patient 6, 29-39y, CKD G4-G5). Q18. *CKD SM is very important...But (peritoneal dialysis) patients with good adherence can lead the whole family to travel abroad*. (HCP1, 29-39y). Q19. *Doctors and nurses are the leading roles, such as...deciding taking medicine. I need to listen to the [medical care of] doctors and nurses*. (Patient 4, 29-39y, CKD G1-G3). Q20. *I should actively cooperate with treatment, follow the taboos or precautions that the doctors recommended.* (Patient 5, 29-39y, CKD G1-G3). Q21. *We as health care professionals play a role in letting patients correctly understand the CKD. Then, we can guide the patients how to adhere to treatment, which is very important*. (HCP4, 29-39y).

CKD, chronic kidney disease; HCP: health care professional; Q: quote; SM, self-management.

Table 4. Representative quotations on current CKD practice, barriers, (anticipated) facilitators and needs toward CKD self-management.

Themes and Subthemes	Representative Quotation
Current CKD practice	
Current SM practice by patients	
Medical management	Q22. *I took medications very regularly. Otherwise, my blood pressure will be high and I can not control it.* (Patient 7, 29-39y, CKD G4-G5). Q23. *I paid attention to the [chronic kidney] disease. If I felt uncomfortable, I quickly measured my blood pressure.* (Patient 4, 29-39y, CKD G1-G3). Q24. *My legs were swollen. I started to restrict water [intake]. Then, the edema slowly disappeared.* (Patient 8, 40-50y, CKD G1-G3). Q25. *I eat food based on doctor's requirements every day, low salt and low fat, and high-quality protein.* (Patient 5, 29-39y, CKD G1-G3).
Role and emotional management	Q26. *I took medicines on time and had a rest every day. I am a patient and just consider medicines every day.* (Patient 11, 51-61y, CKD G1-G3). Q27. *I try to comfort myself. I can not leave medicines...But you are sick and you have to take them. I can focus on the present life*. (Patient 5, 29-39y, CKD G1-G3). Q28. *I do not have much stress on this disease. Because it is useless, I want to live in the present life in a happy way every day.* (Patient 1, 40-50y, CKD G4-G5).
SM skills	Q29. *I used the small spoon to add salt in the food. My blood pressure was as high as 145 or 156 before, now my blood pressure is around 123 after limiting salt intake.* (Patient 11, 51-61y, CKD G1-G3). Q30. *When I searched the [chronic kidney] disease online, I searched the information about the cause of disease, treatment or what precautions I need to care about*. (Patient 5, 29-39y, CKD G1-G3). Q31. T*here is a diet list [for CKD]. Also, I searched the information by asking other patients during hospitalization.* (Patient 6, 29-39y, CKD G4-G5). Q32. *If I saw that I had swollen legs or eyes... I called the doctors and they told me not to put the dialysis fluid in the abdomen for a long time*. (Patient 1, 40-50y, CKD G4-G5). Q33. *I insist on exercising for more than 10,000 steps every day...if I only exercised for four or five thousand, I will go outside to reach 10,000 steps.* (Patient 4, 29-39y, CKD G1-G3).
Implementation of SM intervention by HCPs	Q34. *If patients did not correctly take the medication, you can tell him [the correct way]. When he is prepared for discharge from the hospital, repeat it again*. (HCP1, 29-39y).

Barriers, (anticipated) facilitators and needs toward CKD SM	
Barriers	
Knowledge	Q35. *I did not know that I can not eat red dates. I heard that eating red dates can nourish the blood. My potassium was high and I had serious edema.* (Patient 7, 29-39y, CKD G4-G5).
Environmental context and resources	Q36. *There is no good way. One way is the Wechat public account we created. Another is the internet. But the information is not written by professionals, not true and disordered*. (HCP3, 18-28y).
	Q37. *Patients want detailed information from doctors, for instance, diet and detailed medical advice on all aspects. But the doctor's ward round is tight, and they are busy every day.* (HCP9, 29-39y).
Social influence	Q38. *Patients' families do not follow the strict rules such as dietary habits to assist patients to manage themselves*. (HCP2, 29-39y).
	Q39. *Some patients want to give CKD treatment up. Then, it can be challenging to communicate with them. They would not adhere to lifestyle changes*. (HCP3, 18-28y).
(anticipated) Facilitators	
Knowledge	Q40. *If the patient often read the information related to the disease...he will have a deeper understanding of our medical care. If the knowledge is increased, his SM will be improved*. (HCP3, 18-28y).
Environmental context and resources	Q41. *We have Wechat account, which is trustworthy. It can help them when they ask whether they can eat a specific food, especially when we are too busy to tell them details*. (HCP4, 29-39y).
Social influence	Q42. *My family members are helpful. If there is something I do not understand, he will check it from the Internet. I think this helps a lot*. (Patient 11, 51-61y, CKD G1-G3).
	Q43. *I did not want to have dialysis. But after talking to doctor Xin, I know that I can live for more than ten years with dialysis. Then, I accepted it*. (Patient 3, 40-50y, CKD G4-G5).
Needs	
Knowledge	Q44. *Patients need related knowledge like the diet [restrictions]...such as he can not eat this food or eat less.* (HCP4, 29-39y).
Environmental context and resources	Q45. *I need clear information online...what food I can eat online is not clear and not detailed...The information is conflicting...* (Patient 6, 29-39y, CKD G4-G5).

CKD, chronic kidney disease; HCP: health care professional; Q: quote; SM, self-management.

Theme 1: CKD Illness Perceptions

CKD diagnosis and anticipated consequences of illness (patient Generated)

More than half of patients mentioned that they had a 'late' CKD diagnosis, and attributed this to their limited awareness and recognition of CKD symptoms (table 3, Q1). Patients with CKD mentioned initial difficulties in understanding and accepting their CKD diagnosis (table 3, Q2), as they felt fearful and uncertain about the permanence of CKD, its influence on their future health (table 3, Q3) and the anticipated social and financial burden (table 3, Q4).

Physical, psychosocial and lifestyle Consequences of CKD (patient and HCP Generated)

Patients frequently mentioned that they felt 'discomfort' and 'weakness' because of symptoms such as fatigue (table 3, Q5), especially those with CKD stages G4-G5 (table 3, Q6). Also, both patients and HCPs highlighted the psychosocial impact of CKD. Patients expressed frustration and depression due to their deteriorating health status and impairments in their social life (table 3, Q7). Also, patients mentioned losing their job and facing difficulties in re-entering the workforce as a consequence of CKD; making them feel anxious about their financial situation (table 3, Q8). Additionally, they felt guilt and regret about the burden their disease imposed on family members (table 3, Q9). All these impacts were also observed in the consultations (see Additional file 5: https://bmjopen.bmj.com/content/11/3/e044 059.info).

More than half of patients mentioned that CKD treatment requirements made them feel that they were not living a 'normal life' (table 3, Q10). Also, patients receiving dialysis mentioned that their daily treatment schedule led to difficulties in traveling and engaging in social activities (table 3, Q11).

Theme 2: Understanding of and motivation towards CKD self-management

Understanding of CKD self-management (Patient and HCP Generated)

Patients and HCPs both mentioned that they considered CKD self-management to be solely 'medical management'. However, how they expressed this understanding differed significantly (table 3).

More than half of patients and HCPs described CKD self-management as ‘adherence to medical advice and treatment as prescribed’ (table 3, Q15). Patients also described CKD self-management as ‘being obedient’, literally quoting their HCPs’ medical advice (table 3, Q12-14). Also, HCPs expressed that improving patient disease knowledge as the priority of CKD self-management (table 3, Q16).

Motivation towards CKD self-management (patient and HCP Generated)

Patients expressed the belief that self-management could slow down their disease progression and optimize their health status (table 3, Q17). More than half of HCPs considered CKD self-management as a necessity to control patients’ symptoms and for improving health-related outcomes (table 3, Q18).

Patients believed that HCPs were sufficiently knowledgeable to help them manage their disease (table 3, Q19), and named their own responsibilities within CKD self-management as ‘strictly following medical advice’ (table 3, Q20). HCPs frequently expressed that their role in self-management was to inform patients about the importance of adherence to medical advice and enable this adherence by providing health education (table 3, Q21).

Theme 3: Current CKD practice

Theme 3a: Current self-management practice by patients (patient Generated)

All concepts related to self-management practice by patients are operationalized in Additional file 6 (https://bmjopen.bmj.com/content/11/3/e044059.info) [46, 47].

When asked about their current CKD self-management, patients mostly named concepts related to medical management, such as Disease-specific Controlling Behaviors (DCBs). The most frequently mentioned DCBs were: adhering to medical advice on medication use (table 4, Q22), treatment and regular follow-up, self-monitoring (table 4, Q23) and symptom management (table 4, Q24). Additionally, more than half of the patients mentioned the performance of healthy behavior, such as diet restrictions (table 4, Q25). The discussion of patients’ DCBs was frequently observed in consultations (see Additional file 5: https://bmjopen.bmj.com/content/11/3/e044059.info). Other aspects of self-management, such as role- and emotional management, were not frequently mentioned. Some patients described a shift towards a more passive ‘patient role’ (table 4, Q26). Two patients mentioned the experience of coping with emotional problems (table 4, Q27-28).

Patients frequently named the use of problem-solving- and decision-making skills when experiencing physical symptoms (table 4, Q29). Patients searched and obtained disease-related knowledge from various sources including their HCPs, the internet, hospital brochures and contact with other patients (table 4, Q30-31). These findings were consistent with observation data (see Additional file 5: https://bmjopen.bmj.com/content/11/3/ e044059.info). Other aspects of CKD self-management skills, such as partnering with their HCPs and action planning based on goal setting, were not frequently mentioned. Some patients mentioned that HCPs provided advice on how to cope with symptoms (table 4, Q32), or stated to have created and modified self-management action plans (table 4, Q33).

Theme 3b: Implementation of self-management intervention by HCPs (HCP Generated)

HCPs mentioned facilitating patients’ self-management by providing health education, especially about strict adherence to medical treatment (table 4, Q34). Observations confirmed that CKD-specific health education was frequently provided by HCPs (see Additional file 5: https://bmjopen.bmj.com/content/11/3/e044059.info).

Theme 4: Barriers, (anticipated) facilitators and needs toward CKD self-management

Identified barriers, facilitators, and needs towards CKD self-management were classified using the TDF [43] (details provided in Table 5 and Additional file 7: https://bmjopen.bmj.com/content/11/3/e044059.info).

Barriers

Patients and HCPs frequently named a lack of knowledge of CKD (e.g. symptoms) and difficulties in making necessary lifestyle changes as barriers to patients’ self-management outcomes (table 4, Q35). Moreover, patients and HCPs frequently mentioned barriers related to the environmental context and resources, such as limited (online) education resources and HCPs' time constraints (table 4, Q36-37). Barriers for patients related to 'social influence' were named by HCPs, such as inadequate support from family members (table 4, Q38). Also, HCPs stated that they felt patients' emotional problems interfered with the patient-HCP communication, impeding patients' self-management (table 4, Q39).

(anticipated) Facilitators and needs

Patients and HCPs commonly mentioned that sufficient disease-related knowledge might support patients' adherence to treatment and improve self-management skills (table 4, Q40). Also, patients and HCPs emphasized that access to trustworthy (online) educational resources might facilitate self-management efforts (table 4, Q41). Additionally, patients and HCPs cited adequate family-level support and effective patients-HCP communication as facilitators (table 4, Q42-43). Needs reflected the anticipated facilitators: patients and HCPs expressed the need for better access to and provision of disease-related knowledge (table 4, Q44), especially through eHealth mediums (table 4, Q45).

Table 5. Identified barriers, (anticipated) facilitators of CKD self-management in five domains.

TDF domain	Patient	HCP	Operationalization
Barrier			
Knowledge	X[*]	X	- Patients' lack of general knowledge of CKD - Patients' lack of knowledge on lifestyle changes - Patients' lack of knowledge of treatment
Environmental context and resources	X	X	- Limited education resources or materials for patients' knowledge - Time constraints of HCPs
Behavioral regulation	X		- Patients' insufficient information on lifestyle behavior change - Patients' difficulties in breaking certain habits
Emotion		X	- Patients' experienced fear, anxiety, and depression - Patients' lack of confidence deal with heavy disease burden
Social influence		X	- Inadequate support from family members - Interfered patient-HCP communication
(anticipated) Facilitator			
Knowledge	X	X	- Patients' sufficient general knowledge of CKD (treatment) - Patients' sufficient knowledge of symptom management and lifestyle changes
Environmental context and resources	X	X	- Patients' access to educational resources
Social influence	X	X	- Adequate family-level support - Effective patient-HCP communication
Behavioral regulation	X		- Patients' being able to adhere to the lifestyle changes prescribed

TDF, Theoretical Domains Framework; HCP: health care professional.

[*] Domain mentioned by stakeholder.

DISCUSSION

The beliefs, perceptions and needs of patients with CKD and HCPs regarding CKD self-management were examined. Our study revealed that almost all patients and HCPs solely mention the medical management of CKD: self-management is largely unknown or misinterpreted as adherence to medical treatment. Also, both patients and HCPs mentioned heavy psychosocial impact resulting from CKD. Furthermore, we found that a paternalistic patient-HCP relationship was often present.

Our finding that self-management is often misinterpreted as adherence to medical treatment underlines the importance of education on the core concepts and possible advantages of self-management interventions. Self-management is comprised of medical, emotional, and role management [11], and it aims to optimize the uptake of meaningful behaviors or life roles, promoting adequate coping with disease consequences [11]. Hence, if patients and HCPs do not fully understand the concept of self-management, this might influence their uptake of self-management interventions in practice [47, 48]. A recent review examined the effectivity of interventions to educate professionals on how to support patient self-management through eHealth [49]. For example, blended learning that combines e-learning and face-to-face methods is suggested to support self-management skills development for HCPs [49]. Also, improving health literacy, namely the ability to access, process, comprehend, use health information and to effectively communicate with HCPs about health information, has been associated with successful disease self-management of patients with CKD [50]. An intervention that focusses on education about self-management and aims to improve health literacy may improve the chances of successful uptake of self-management behaviors.

Patients almost never mentioned the psychosocial aspects of self-management, but they did mention the heavy psychosocial impact resulting from CKD. Considering this contradiction, we advise future research and developers in China to increase their focus on the psychosocial aspects of CKD and to contemplate the use of cognitive-behavioral therapy elements [51] to help manage this impact. Also, patients' self-efficacy and ultimately their self-management health behaviors [52-54], are associated with psychosocial well-being, making an increased focus on the psychosocial aspects of the disease as a prerequisite for successful disease self-management in general.

Consistent with previous literature [55], patients with CKD stages G4-G5 in our study frequently mentioned a heavy symptom burden. However, these patients did not express a greater need for self-management interventions, as we would expect from previous research [55]. This may be explained by the fact that patients cannot ask for things they do not know: Patients' misinterpretation of self-management may have limited their ability to express their needs. Also, as patients with CKD G4 or G5 have often suffered from the disease for a long period, they may have adapted to living with their disease and therefore feel less need for self-management interventions.

Patient autonomy is a core principle of the patient-doctor interaction in Western cultures [56, 57]. However, under certain conditions, the paternalistic relationship we encountered in our study can be valuable and even essential to improving health outcomes and treatment adherence in some cultural contexts, for instance, if patients prefer a paternalistic approach over autonomy [58, 59]. We advise not to try and eliminate this paternalistic relationship but to incorporate its potentially positive aspects in self-management interventions. Also, improving patient activation has been an important factor for successful self-management and should be fostered [60, 61]. Previous literature has showed that a higher level of patient activation is associated with higher levels of self-care in patients with CKD [61]. Hence, we argue that it is important to focus on and improve patient activation before implementing self-management intervention, especially considering the current dominant patient-HCP relationship. For example, an intervention can be developed by building patients' skills in posing more and better questions to their doctors and in recognizing the importance of asking questions in the decision-making process [62]. Additionally, increasing patients' empowerment can be an effective way to facilitate shared decision-making. A more individualized and specialized empowerment intervention is needed [63], for instance, by providing patients with tailored education and psychosocial support including a focus on self-confidence. Such an intervention can increase patients' awareness of self-management behaviors and strengthen their ability to successfully manage their disease and life.

A barrier to adequate self-management that was frequently reported by patients is a lack of knowledge. We found that the use of eHealth was largely supported by patients and HCPs to address this barrier. As such, we advocate the development of a national, trustworthy health education resource platform to address the needs expressed by patients for access to reliable medical information. As an example, an evidence-based health information website (http://www.thuisarts.nl) in the Netherlands has effectively improved self-management and reduced healthcare usage [64]. However, previous literature showed that only increasing patients' knowledge was insufficient to modify their behavior [65]. Thus, we highlight the importance of also improving both patients' motivation and their behavioral skills to facilitate their CKD self-management. As an example, serious gaming has the potential to improve patients' motivation and behaviors of self-management. China has numerous internet and mobile phone users [66], and serious gaming is cost-effective, flexible, portable and could invoke intense and durable interest among patients and HCPs in engaging in regular self-management (implementation) [67].

To our knowledge, this is the first study to describe the beliefs, perceptions and needs towards CKD self-management of patients and HCPs in China. We performed an exploratory, cross-sectional study taking a basic interpretive (generic) qualitative research approach [29]. We argue that this approach is most suitable for examining the individual beliefs, perceptions and needs towards CKD self-management, as it allows us to provide a low-inference description of the phenomenon of interest, allows us to combine inductive and deductive reasoning while building on the existing knowledge base on this topic mostly derived from research performed in western countries. We also considered taking a phenomenological approach. However, we were not primarily interested in the inner dimensions or essence of the concepts and processes that we investigated. Instead, we were interested in the participants' interpretation of the beliefs, perceptions and needs themselves. In other words, we wanted to know what patients believed, and not necessarily how these beliefs came to be. Grounded theory was not an option, as we did not aim to build a theory from scratch explaining (the interaction between) these concepts (like one would when applying a grounded theory approach). As we are aware of the pitfalls of generic qualitative research [68, 69], we therefore adhere to the 'big-tent' criteria for excellent qualitative research. Tracy et al [70] suggest that when designing qualitative research, developers should focus on the 'ends' rather than getting stuck in methodology-bound ‘means’. Also, we follow the guidance provided on how to perform and report on generic qualitative research [68, 69] to optimize the quality and the validity of the results. Moreover, the framework method for data analysis is consistent with our research design, as it is not aligned with a particular epistemological, philosophical, or theoretical approach to qualitative research. Instead, it can be (adapted) for use in different approaches that aim to examine specific topics or themes [71]. It is furthermore especially suitable for multidisciplinary health research that includes both patients and HCPs [42]. The framework method can be used for both inductive and deductive coding to understand the phenomenon of interest. In our study, we expand and falsify existing knowledge on beliefs, perceptions and needs about CKD. We thus need to combine the inductive and deductive aspects of coding, making the framework method an excellent match. By using the framework approach, we clearly and systematically detail the steps performed as well as the perspective taken on the data collection and the analysis process, hence preventing ‘method slurring’ [72]. Additionally, other strategies to optimize quality and the validity of the results were adopted. As our study includes the triangulation of data sources, rigor was established in the data collection and analysis process.

Nevertheless, there are also limitations. First, as our findings were not quantified, the relative importance of influencing factors (e.g. paternalistic patient-HCP relationship) for CKD self-management could not be determined. Second, the HCPs who provided CKD care in the institution were predominantly female. The HCP group interviewed was not representative of all HCPs in Nephrology practice. This selection bias might be caused by the fact that participants who were more positive towards self-management were more likely to participate in our study. However, the number of negative experiences and barriers identified in this study might indicate that this bias has remained limited. Due to time restrictions, participants were not asked to provide feedback on the transcripts and results. However, during the interviews, the interviewer often summarized her interpretation of participants’ answers in order to receive clarifications and confirmation.

CONCLUSIONS

This study provides a comprehensive overview of patients' and HCPs' beliefs, perceptions and needs towards CKD self-management in China. To optimize the implementation of self-management interventions, future developers should be mindful of the limited understanding of CKD self-management and prepare their interventions accordingly. Also, considering the heavy psychosocial impact of CKD, the focus of self-management interventions should be put on enhancing patients' role management and emotional skills. We advise developing intervention components tailored to the specific cultural context to improve CKD self-management implementation in developing countries. With this approach, selected self-management intervention elements can be implemented using eHealth mediums.

Authors' contributions

HS led the design of this study and is the main contributor in writing this manuscript, with contributions from all authors. HS and WW participated in data collection and analysis. RK, PB, XS, ZL, XL and and NC contributed to the design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Funding

This work was supported by the China Scholarship Council (CSC) (grant number 201707040096).

Competing interests

None declared.

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Chapter 6

Digital tools/ eHealth to support CKD self-management: a qualitative study of perceptions, attitudes and needs of patients and health care professionals in China

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Submitted

Abstract

Background

A growing body of evidence supports the potential effectiveness of electronic health (eHealth) self-management interventions in improving disease self-management skills and health outcomes of patients suffering from chronic kidney disease (CKD). However, current research on CKD eHealth self-management interventions has almost exclusively focused on high-income, Western countries. To adapt and evaluate a tailored eHealth self-management intervention for patients with CKD in China based on the Dutch Medical Dashboard (MD) intervention, we examined the perceptions, attitudes and needs of Chinese patients with CKD and health care professionals (HCPs) towards eHealth based (self-management) interventions in general and the Dutch MD intervention in specific.

Methods

We conducted a basic interpretive, cross-sectional qualitative study comprising semi-structured interviews with 11 patients with CKD and 10 HCPs, and 2 focus group discussions with 9 patients with CKD. This study was conducted in the First Affiliated Hospital of Zhengzhou University in China. Data collection continued until data saturation was reached. All data were transcribed verbatim and analyzed using a framework approach.

Results

Three themes emerged: (1) experience with eHealth in CKD (self-management), (2) needs for supporting CKD self-management with the use of eHealth, and (3) adaptation and implementation of the Dutch MD intervention in China. Both patients and HCPs had experience with and solely mentioned eHealth to '*inform*, *monitor and track*' as potentially relevant interventions to support CKD self-management, not those to support '*interaction*' and '*data utilization*'. Factors reported to influence the implementation of CKD eHealth self-management interventions included information barriers (i.e. quality and consistency of the disease-related information obtained via eHealth), perceived trustworthiness and safety of eHealth sources, clinical compatibility and complexity of eHealth, time constraints and eHealth literacy. Moreover, patients and HCPs expressed that eHealth interventions should support CKD self-management by improving the access to reliable and relevant disease related knowledge and optimizing the timeliness and quality of patient and HCPs interactions. Finally, suggestions to adaptation and implementation of the Dutch MD intervention in China were mainly related to improving

the intervention functionalities and content of MD such as addressing the complexity of the platform and compatibility with HCPs' workflows.

Conclusions

The identified perceptions, attitudes and needs towards eHealth self-management interventions in Chinese settings should be considered by researchers and intervention developers to adapt and evaluate a tailored eHealth self-management intervention for patients with CKD in China. In more detail, future research needs to increase eHealth literacy and credibility of eHealth (information resource), ensure eHealth to be easy to use and well-integrated into HCPs' workflows.

INTRODUCTION

Chronic kidney disease (CKD) is a severe public health problem [1, 2], and has a global prevalence of 9.1% [3]. CKD is categorized into five stages based on the glomerular filtration rate decline and level of albuminuria [4]. The disease burden of CKD is significant: patients with CKD often report severe impairment in health-related quality of life and experience adverse health outcomes [5, 6]. Moreover, CKD imposes a substantial economic burden due to its considerable health-related and societal cost [7, 8].

Interventions promoting adequate disease self-management (further referred to as self-management) of CKD can optimize a patient's ability to perform the cognitive, behavioral, and emotional behaviors necessary to achieve a satisfactory level of health-related quality of life [9]. Additionally, interventions supporting self-management can not only improve self-management behaviors [10-12], but also health outcomes [13], and may even slow disease progression [14-16]. Hence, optimizing CKD self-management is of utmost importance to reduce disease burden, improve health outcomes and control health care expenditures [14].

Electronic health (eHealth) based interventions are increasingly being developed to support CKD self-management. Previous evidence suggests that eHealth self-management interventions can be effective in improving healthy behaviors and health outcomes of patients with CKD [17-19], and increasing healthcare accessibility and efficiency [20]. An example of an extensively studied and effective CKD eHealth self-management intervention is 'Medical Dashboard (MD)' [21-23]. The MD, developed in the Netherlands, enables patients and health care professionals (HCPs) to monitor and track healthy behaviors and disease parameters. Such an effective MD eHealth based self-management intervention is of practical relevance for China, with the highest number of patients being affected by CKD (132 million) [24] and accounting for around one fifth of the global burden of CKD [24, 25]. Also, patients and HCPs face challenges in the accessibility of CKD care due to the lack of a strong primary care system in rural China. Therefore, it is essential to adapt and tailor effective CKD eHealth self-management interventions, for instance, the Dutch MD intervention, to decrease the CKD burden in China.

To successfully adapt and tailor effective eHealth self-management interventions for patients with CKD in China, it is important to align the interventions with key users' needs and perceptions [26, 27]. As noted in the Health Belief Model [28], the Theory of Planned Behavior [29] and Technology Acceptance Model [30], individuals' perceptions (i.e. the organized cognitive representations that individuals have about a subject), attitudes (i.e. an individual's overall evaluation of a subject based on certain perceptions) and needs (i.e. demands and requirements that people require to address their problems) can predict their uptake and acceptance of (eHealth) interventions. However, as of yet, little knowledge is available on these perceptions, attitudes and needs towards eHealth interventions supporting CKD self-management, especially for China and other low- and middle-income countries (LMICs).

Therefore, our ultimate goal is to adapt and evaluate a tailored eHealth self-management intervention for patients with CKD in China based on the Dutch MD intervention. To inform these adaptations and evaluations, two qualitative studies were performed. The first study examined the perceptions and needs of patients with CKD and HCPs towards CKD self-management in China [31]. This paper describes the results of the second qualitative study and comprises two parts examining:

- Part A: the perceptions, attitudes and needs of patients with CKD and HCPs towards eHealth-based (self-management) interventions in general.
- Part B: the perceptions, attitudes and needs of patients with CKD and HCPs towards the Dutch MD intervention in specific.

METHODS

Study design

We performed a basic interpretive, cross-sectional qualitative study comprising semi-structured interviews and focus group discussions. The core intervention components, functionalities and supporting screenshots of MD are presented in Textboxes 1-2. The methods are further detailed in Table 1. More details on the overarching study have been described elsewhere [32]. For the reporting, we adhered to the Consolidated Criteria for Reporting Qualitative Health Research (COREQ) [33] in this study.

Ethics approval and informed consent

This study was approved by the Ethics Committee of the First Affiliated Hospital of Zhengzhou University (reference number 2019-KY-52). Participants were informed about the nature of the research project, the possible risks and benefits and their rights as research participants. If they agreed to participate, written informed consent was obtained.

Study participant and recruitment

Our study was conducted in the First Affiliated Hospital of Zhengzhou University in the Henan province in China. Participants were recruited from January to April 2019. Study invitation strategies included the provision of flyers and face-to-face verbal invitations for both patients and HCPs, and an online invitation for HCPs. Additional information regarding study setting and recruitment procedures can be found elsewhere [32]. The eligibility criteria for study inclusion of patients with CKD and HCPs are detailed in Table 2.

We followed the principles of ‘purposive and convenience sampling’ [34] to capture a diverse sample concerning demographic- (e.g. age) and clinical (e.g. CKD stage) characteristics. Also, we used snowball sampling [35] to identify additional participants, in which current participants were asked if they knew any other individual who could participate in the study. Patients and HCPs received a reimbursement (20 RMB of telephone credits) to compensate for their time.

Textbox 1. Core intervention components and functionalities of Medical Dashboard.

- **Motivational interviewing:** Patients are provided with a one-hour individual motivational interview, which focuses on discussing barriers, benefits, and strategies for self-management; setting personal goals, and strengthening intrinsic motivation and self-efficacy.
- **Education:** Patients are provided with education, a kidney-friendly cookbook, instructions for self-monitoring blood pressure (using a Microlife Watch blood pressure home device), dietary intake (using an online food diary) and 24-hour urinary sodium excretion (using an innovative point-of-care chip device).
- **Self-monitoring**: Patients are instructed to take health measurements at home (e.g. blood pressure, weight and glucose) and enter the results of these measurements via the secure “self-care” website www.bonstat.nl. The measurements entered via this website are linked real-time to the Medical Dashboard interface.
- **Combination of home and hospital measurements in the Medical Dashboard**: The measurements that patients take at home and the measurements performed during hospital visits are visualized jointly in the Medical Dashboard.
- **Online information support**: Patients are provided with online disease-related information, tips and suggestions focusing not only on medical knowledge, but also on how to obtain and sustain social support, refusal skills, medication adherence strategies, physical exercise, healthy eating, smoking cessation and reduced alcohol intake.
- **Personal coaching**: Patients are coupled with one of four personal coaches: three health psychologists and one dietician. Following the self-monitoring measurements, patients are provided with feedback by telephone from their coach or during hospital visits. The discussion focuses on the progression, achievements, barriers and possible solutions of self-management.

Textbox 2. Core Medical Dashboard intervention print screenshots.

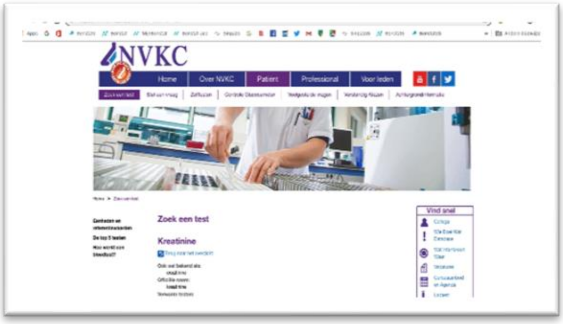
Self-monitoring and combination of home and hospital measurements in the Medical Dashboard:

	Meting	Datum	Waarde		Persoonlijk	Algemeen
	Biometrisch					
Z	Bloeddruk ZH (mmHg)	[illegible]	140/85	🟩	< 140/85	< 140/90
T	Bloeddruk Thuis (mmHg)	[illegible]	130/78	🟩	< 130/80	< 130/80
	Laboratorium					
Z	Cholesterol (LDL) (mmol/l)	[illegible]	4,2	🟥	< 3,0	< 2,6
	Voeding					
T	energie (kcal)	[illegible]	2450	🟩	2500	2500
T	Natrium (mg)	[illegible]	4000	🟥	< 3600	< 2400
	Beweging					
T	Aantal stappen/dag	[illegible]	5700	🟩	[illegible]	10.000

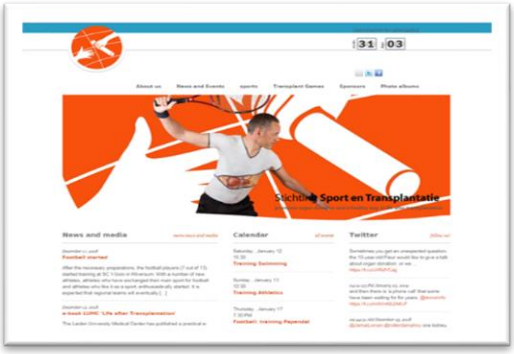
(A) Patients' self-measurements and hospital data are visualized jointly in the Medical Dashboard.

Online information support

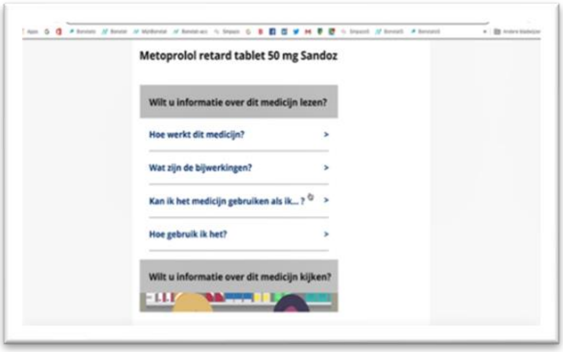
(B) Overview of online information support



(C) Information of laboratory tests (e.g. creatinine)



(D) Information of healthy lifestyle



Metoprolol retard tablet 50 mg Sandoz

Wilt u informatie over dit medicijn lezen?

Hoe werkt dit medicijn? >

Wat zijn de bijwerkingen? >

Kan ik het medicijn gebruiken als ik... ? >

Hoe gebruik ik het? >

Wilt u informatie over dit medicijn kijken?

(E) Information of medication use (e.g. Metoprolol)

Table 1. Field methods for research topics.

Method	Part A: Perceptions, attitudes and needs towards eHealth based (self-management) interventions for CKD in general		Part B: Perceptions, attitudes and needs towards the Dutch Medical Dashboard self-management intervention in specific	
	Patients	HCPs[a]	Patients	HCPs
Semi-structured interviews	X	X		X
Focus group discussions			X	

[a]HCPs, health care professionals.

Table 2. Eligibility criteria for patients with chronic kidney disease and health care professionals.

Category	Participant eligibility criteria
Inclusion criteria	• Patients: (1) aged over 18 years old; (2) a diagnosis of chronic kidney disease (CKD) with markers of kidney damage or a glomerular filtration rate of less than 60 ml/min/1.73m^2 persisting for ≥3 months based on Kidney Disease Improving Global Outcomes (KDIGO) guidelines; (3) all CKD stages (stage G1-G5) following the KDIGO staging of CKD; (4) Chinese speaking. • Health care professionals (1) who work in the Department of Nephrology of the First Affiliated Hospital of Zhengzhou University (2) are able to implement the intervention in their daily practice
Exclusion criteria	• Individuals unable to provide written informed consent and/or use the electronic application due to physical disabilities such as eyesight problems or mental disabilities such as psychosis, personality disorders or schizophrenia (final decision for exclusion to be made by the treating physician) • Individuals unable to write or read.

Research materials

The interviews and focus group topic lists were developed based on similar studies into users' perceptions and needs towards eHealth intervention implementation [36, 37] and refined through research team discussions.

- **Part A:** To examine the perceptions, attitudes and needs of patients and HCPs towards eHealth based (self-management) interventions for CKD in general, the semi-structured interview guide was theory-driven; concepts of the Health Belief

Model [28] and the Theory of Planned Behavior [29] were used to develop the topic list.

- **Part B:** To examine the perceptions, attitudes and needs of patients and HCPs towards the Dutch MD intervention in specific, participants were prompted with information and screenshots detailing the intervention content and design features of the MD intervention via a PowerPoint presentation.

Research materials were piloted to verify their feasibility and acceptability for patients and HCPs.

Data collection

One researcher (HS, female, a PhD student focusing on eHealth applications in chronic disease self-management, master's degree in nursing, expertise in qualitative research) conducted the semi-structured interviews and focus group discussions (Table 1). The interviewer had no contact or relation with any participant before the study. Also, the interviewer was formally trained and had ample experience with qualitative research. To ensure confidentiality and privacy, face-to-face interviews and focus group discussions were performed in a private room in the hospital department. Each topic started with an open-ended question, then follow-up questions, and prompts were used when needed. The sample size for the interviews and focus group discussions was not predetermined, but based on when data saturation was achieved, being the point at which no new or relevant information could be identified through the iterative, preliminary analysis of the data [38]. All semi-structured interviews and focus group discussions were audio-recorded with a digital voice recorder. Field notes detailing the interview setting, atmosphere, and participants' non-verbal behaviors enabled a richer analysis of the data. Also, we collected participants' sociodemographic- and clinical characteristics via the patient medical records.

Data analysis

A Framework Method [39] was used to guide our qualitative analysis.

Stage A and B: Transcribing and Familiarization

All audio-taped semi-structured interviews and focus group discussions were anonymized and transcribed verbatim. Names and identifiers were removed to protect participant confidentiality. One researcher performed transcription, and another researcher checked transcripts to ensure content accuracy. Before coding, the two researchers independently read transcriptions full text to become familiar with the data.

Stage C: Development of an analytical framework & coding

Atlas.ti for Windows version 7.5.18 (Scientific Software development, Berlin) was used for data analysis. Initial coding trees were developed based on the theoretical framework developed in our study protocol [32] and the Technology Acceptance Model [30]. The final coding tree was built in two steps. First, the independent coding of three transcripts using the initial coding tree by two researchers was compared, with differences highlighted. Next, differences were discussed in the research team until consensus was reached. After, one researcher (HS) coded all transcripts using the final coding tree; codes were verified by a second researcher (WW).

Stage D: Charting data into the framework matrix

Data were further reduced by formulating within-cases and cross-cases [40]. Next, data were charted into matrices per research question using Microsoft Excel 2010 and reviewed by all authors. The matrix comprised of one row per participant and one column per code.

Stage E: Interpreting the data

Themes were generated from codes derived from the data set by reviewing the matrix and making connections within and between participants and codes. Emergent themes were then organized into major themes and subthemes. All themes were discussed among the research team and modified if needed.

RESULTS

Participant, interview and focus group discussion characteristics

A total of 21 semi-structured interviews (11 patients with CKD and 10 HCPs) and 2 focus group discussions with 9 patients were conducted (Tables 3-4, Additional file 1).

Table 3. Participant characteristics: HCPs.

Characteristics	Value (N=10)
Age (years), mean (SD)	33 (6.1)
Age (years), n (%)	
21-30	4 (40)
31-40	5 (50)
41-50	1 (10)
Gender, n (%)	
Female	9 (90)
Job occupation, n (%)	
Nurse	7 (70)
Nephrologist	3 (30)
Marital status, n (%)	
Never married	2 (20)
Married	8 (80)
Highest level of education completed, n (%)	
Bachelor’s degree	5 (50)
Master’s degree	3 (30)
Doctoral degree	2 (20)
Years of work experience in medical practice, n (%)	
<5	2 (20)
5-10	3 (30)
>10	5 (50)
Years of work experience in nephrology practice, n (%)	
<5	3 (30)
5-10	3 (30)
>10	4 (40)

Table 4. Participant characteristics: patients with CKD.

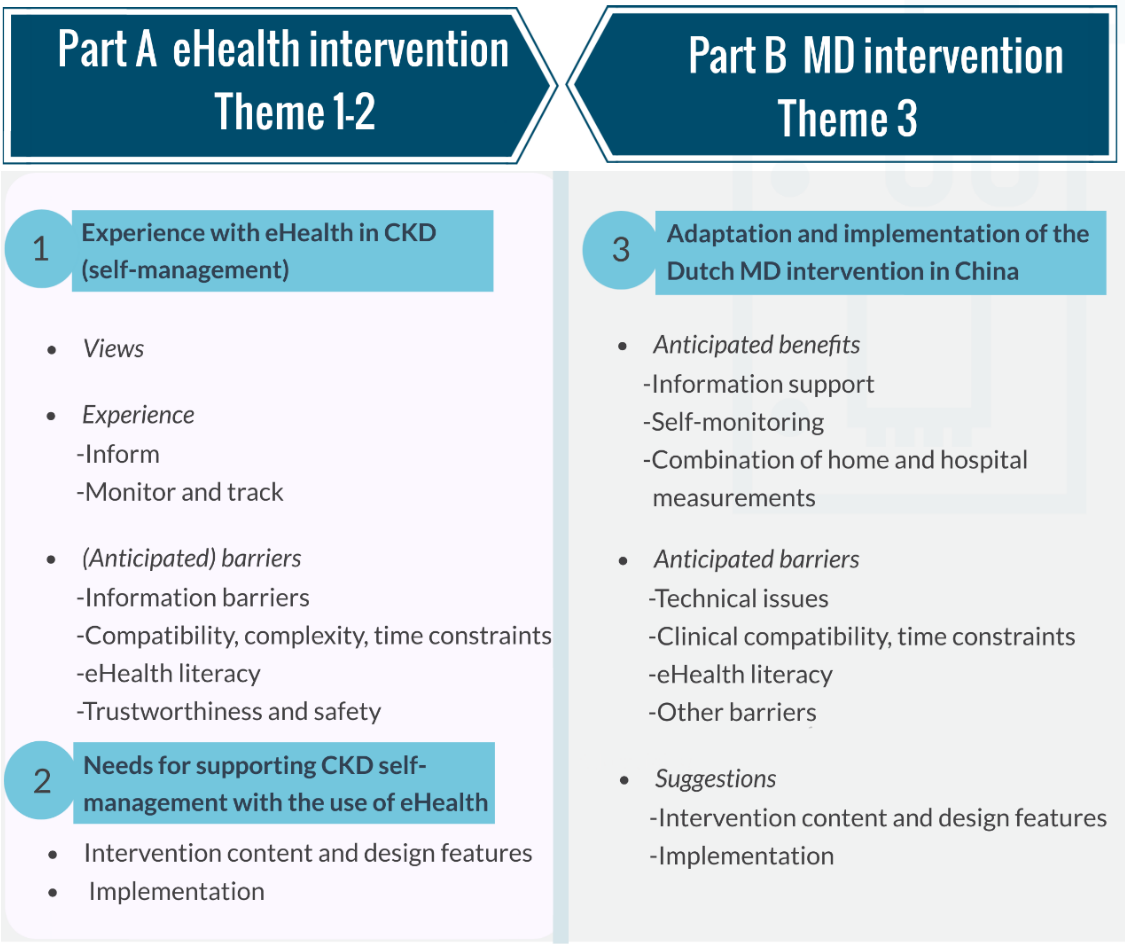
Characteristics	Value	
	Face to face interview (n=11)	Focus group discussion (n=9)
Age (years), mean (SD)	38.9 (9.6)	43.3 (13.2)
Age category (years), n (%)		
18-28	1 (9)	1 (11)
29-39	4 (36)	1 (11)
40-50	4 (36)	3 (33)
51-61	2 (19)	3 (33)
>61	0 (0)	1 (11)
Gender, n (%)		
Female	6 (54)	5 (56)
Marital status, n (%)		
Never married	1 (9)	1 (11)
Married	9 (82)	8 (89)
Divorced	1 (9)	0 (0)
Highest level of education completed, n (%)		
≤Primary school	3 (27)	5 (56)
Middle school	3 (27)	2 (22)
≥High school graduate	5 (46)	2 (22)
Employment status, n (%)		
Employed (full time & part-time)	2 (18)	2 (22)
Not employed	7 (64)	2 (22)
Farming	0 (0)	4 (45)
Student	1 (9)	1 (11)
Retired	1 (9)	0 (0)
Time since CKD[a] diagnosis, n (%)		
<1 year	5 (46)	7 (78)
1-5 years	3 (27)	2 (22)
>5 years	3 (27)	0 (0)
Current CKD[a] stage, n (%)		
Non-dialysis-dependent CKD G1-G3	5 (46)	6 (67)
Non-dialysis-dependent CKD G4-G5	3 (27)	3 (33)
Home peritoneal dialysis CKD G5	3 (27)	0 (0)

[a] CKD, chronic kidney disease.

Themes

Three major themes (Part A: Theme 1-2; Part B: Theme 3) emerged from our data for both patients and HCPs (Figure 1). Themes and subthemes are described in the following sections; illustrative quotations and frequencies are provided.

Figure 1. Overview of themes and subthemes from the analysis. MD: Medical Dashboard.



Part A

Theme 1: Experience with eHealth in CKD (self-management)

Views of eHealth in general (patient and HCP generated)

When asking patients and HCPs about their definition of eHealth, all of them had heard about eHealth. Patients described eHealth as the technology used to educate, monitor (un)healthy behaviors, and facilitate communication between patients and HCPs. When asking patients and HCPs if they could name specific examples of eHealth, they largely mentioned concepts related to telemedicine (7/21, 33%). For example, one patient stated: *eHealth is that [...] I can ask HCPs questions about treatment and diagnosis [of CKD] [...] with remote video calls [with the HCPs].* [Patient 4, male, 37y, CKD 2]

To further enquire on patients' eHealth use, we operationalized eHealth into three types following previous categorizations [41, 42] (Table 5). Patients and HCPs mostly named they frequently used eHealth to '*inform*' and '*monitor and track*'. Other types of eHealth such as those facilitating '*interaction*' and '*data utilization*' were not frequently used.

Table 5. The operationalization of types of eHealth.

Types of eHealth	Operationalization
Inform, monitor and track	eHealth technologies to observe and study health parameters
• Inform	eHealth to educate
• Monitor and track	eHealth to monitor (un)healthy behaviour
Interaction	eHealth to facilitate communication between all health care participants
Data utilization	eHealth to collect, manage, and research data on health

Experience with eHealth use

eHealth to inform (patient and HCP generated)

Patients frequently cited they used their mobile phones to obtain disease-related information through search engines (9/11, 82%) such as Baidu (a Chinese search engine) (Textbox 3, quote 1). More than half of HCPs mentioned using eHealth to provide health education such as medical advice on symptom management to patients. For instance, HCPs mostly named they frequently used mobile phone apps for providing health education (7/10, 70%), predominantly WeChat (an online social network and chat app from the Chinese company Tencent) (6/10, 60%) (Textbox 3, quote 2). Additionally, when eHealth technology was used by HCPs to 'inform', they frequently cited that it benefited their medical practice (7/11, 64%); among which 'saving time on patients' health education' (Textbox 3, quote 3) and 'improving the ability to illustrate practical medical advice with videos or animations' (Textbox 3, quote 4). Patients also mentioned benefits of eHealth use, mostly related to highly improved access to 'easily understandable information' (Textbox 3, quote 5).

eHealth to monitor & track (patient and HCP generated)

When asked about their experience with eHealth, about one-third of patients mentioned the use of eHealth to monitor and track health parameters (4/11, 36%). For example, those receiving peritoneal dialysis mentioned that they downloaded apps on their smartphone to self-monitor physiological parameters (e.g. blood pressure or weight) (Textbox 3, quote 6). Almost half of the patients also mentioned benefits of app-based self-monitoring, mostly related to 'ease of use' in comparison to tracking their measurements on paper (Textbox 3, quote 7). No patients depicted any downsides of eHealth to monitor and track. Additionally, 6 out of 10 HCPs mentioned that they anticipated that improved self-monitoring by patients improves patients' health behaviors, and also helped HCPs to provide accurate medical advice, based on the changes in parameters or symptoms tracked (5/10, 50%) (Textbox 3, quote 8).

(anticipated) Barriers to using eHealth technology

Information barriers (patient and HCP generated)

More than half of the patients (7/11, 64%) and HCPs (7/10, 70%) cited barriers related to the quality and consistency of the disease-related information obtained via eHealth. Patients and HCPs frequently named that information is 'not tailored to their personal needs', 'not practical and detailed', and they sometimes encounter that information is 'inconsistent when consulting different websites or apps' (Textbox 3, quotes 9 and 10).

Trustworthiness and safety (patient and HCP generated)

Patients (6/11, 55%) and HCPs (5/10, 50%) frequently noted barriers related to trustworthiness and safety of eHealth resources. Patients commonly expressed concerns about whether websites contained accurate information (Textbox 3, quote 11). Also, patients mentioned that they did not consult HCPs online because they did not trust unfamiliar doctors (Textbox 3, quote 12). HCPs frequently mentioned that they were reluctant to communicate with patients or provide medical advice online, as they were concerned regarding the reliability and credibility of the information patients provided in online consultations (Textbox 3, quote 13).

Compatibility, complexity of eHealth and time constraints (HCP generated)

Half of the HCPs mentioned the 'complexity of eHealth' and 'a lack of compatibility of eHealth use with their workload and scope of practice' as barriers. HCPs frequently mentioned that the extra tasks and burden eHealth introduced into their already busy daily schedule increased their work stress (4/10, 40%) (Textbox 3, quote 14).

eHealth literacy (HCP generated)

Almost half of HCPs mentioned patients' level of eHealth literacy as a barrier towards eHealth use (4/10, 40%). For example, HCPs stated they experienced that several of their patients have too little eHealth experience, knowledge, and skills to adequately use eHealth in practice (Textbox 3, quote 15).

Textbox 3. Illustrative quotations for theme 1: experience with eHealth in CKD (self-management).

eHealth to Inform

- **Quote 1**: I often search [information of] this [chronic kidney] disease using Baidu. [...] the treatment or what precautions I need to care about. (Patient 5, male, 35y, CKD G3)
- **Quote 2:** WeChat is used to meet patients' knowledge needs. (HCP2, female, 30y)
- **Quote 3**: The process of patients' asking [medical] questions can be simplified. [...] When patients asked for information, I can show them videos, which is easy. (HCP5, female, 34y)
- **Quote 4**: The animation and videos we provided during routine care [....] The content can help patients easily understand the diet restrictions and medication use. (HCP5, female, 34y)
- **Quote 5:** The articles HCPs posted are practical. [...] I can have a general understanding of the disease. (Patient 8, female, 45y, CKD G1)

eHealth to Monitor & track

- **Quote 6**: The software on the mobile phone can record my weight, how much the dialysis fluid enters and exits. (Patient 1, male, 42y, CKD G5 with peritoneal dialysis)
- **Quote 7**: [Monitoring parameters in] the app is easier and much more convenient than recording them in a notebook. (Patient 7, female, 32y, CKD G5 with peritoneal dialysis)
- **Quote 8:** Patients put their information into the apps. Then, we can develop the therapy plan that suits them better according to their status at home. (HCP6, female, 33y)

Information barriers

- **Quote 9**: The information in Baidu or other websites is not detailed. (HCP9, female, 39y)
- **Quote 10**: Online knowledge of food with high potassium is not detailed and sometimes conflicting. (Patient 6, male, 34y, CKD G5 not dialysis)

Trustworthiness and Safety

- **Quote 11**: I cannot completely trust the information online. Maybe it is not correct. (Patient 8, female, 45y, CKD G1).
- **Quote 12**: I do not know the experts on the internet and whether he or she is a real doctor [...] So I do not trust the online consultation. (Patient 4, male, 37y, CKD G2).
- **Quote 13**: Although patients submit some measurements online, the data may be not accurately measured [...] Providing medical advice online is risky. (HCP6, female, 33y).

Compatibility, complexity of eHealth and time constraints

- **Quote 14**: We now have an app for helping monitor patients' data. [...] However, we need to submit medical data in this app. [...] (HCP9, female, 39y)

eHealth literacy

- **Quote 15**: Some patients do not know how to use the internet, [...] and some [patients] find it complicated to submit data online. (HCP2, female, 30y)

Theme 2: Needs for supporting CKD self-management with the use of eHealth

Intervention content and design features

eHealth to inform (patient and HCP generated)

Patients (4/11, 36%) and HCPs (6/10, 60%) frequently expressed a need for eHealth as a medium to improve access to disease-related knowledge (Textbox 4, quote 16). More precisely, patients and HCPs frequently named the possible benefits of using eHealth to improve access to personalized information that is relevant and conducive to the specific patients' health needs (Textbox 4, quote 17).

eHealth to facilitate interaction between patients and HCPs (patient generated)

Almost half of the patients mentioned a need for eHealth to support their communication with HCPs outside of clinical visits (4/11, 36%), enabling more individualized support and advice (Textbox 4, quote 18). Moreover, they mentioned that eHealth may provide possibilities to follow-up on their physical symptoms in between consultations (Textbox 4, quote 19).

Design features of eHealth (patient and HCP generated)

Both patients and HCPs mentioned they preferred the use of mobile phone apps instead of personal computers for CKD self-management, as they found that apps were more easily accessible. To facilitate the transfer of disease-related knowledge, half of the HCPs mentioned that animations or videos without medical terminology should be included to support spoken words or text in eHealth interventions (5/10, 50%). Details are provided in Additional file 2.

Implementation and practicality

eHealth credibility (patient generated)

Patients frequently mentioned that the high perceived credibility of eHealth interventions was essential for successful uptake and implementation (4/11, 36%). Specifically, patients mentioned that if interventions were developed by credible eHealth developers such as the government or hospitals, it would facilitate their eHealth use. In more detail, patients mentioned that this would ensure them that the information came from a reputable and trusted source, as they described (their) HCPs as trusted and familiar (Textbox 4, quotes 20).

Textbox 4. Illustrative quotations for theme 2: needs for supporting CKD self-management with the use of eHealth.

Intervention content and design features

- **Quote 16**: If we can make some videos in the department [of nephrology], the patients will learn more [about disease], [...] such as the food they should eat. (HCP5, female, 34y)
- **Quote 17**: I think that it can be better if there are some detailed guidance and those are tailored for me, not for everyone. (Patient 11, female, 51y, CKD G3)
- **Quote 18**: I hope that [...] I can get a reply tailored to my condition through online consultation. [...] (Patient 2, female, 18y, CKD G1)
- **Quote 19:** It is good if patients can talk to the doctor online if they have minor problems [related to disease] at home, [...] such as getting a cold. (Patient 8, female, 45y, CKD G1)

Implementation and practicality

- **Quote 20**: eHealth applications need to be certified and trusted. For example, WeChat is trusted by everyone. [...] Also, the experts who register in the applications need to be trusted, [...] such as with a detailed introduction of their medical background. (Patient 4, male, 37y, CKD G2)

Part B

Theme 3: Adaptation and implementation of the Dutch MD intervention in China

Anticipated benefits of MD

Online information support (patient and HCP generated)

Patients frequently noted that ‘online information support’ feature of MD could improve their access to trusted disease-related knowledge; It would enable them to find information quickly and address their questions without a clinic visit or contacting their HCP (Textbox 5, quote 21). Also, almost half of HCPs cited the possible benefits of the component ‘online information support’ of MD (4/10, 40%) especially related to ‘trustworthiness and safety of the information sources’ (Textbox 5, quote 22), ‘easy access to lab results- and related knowledge to educate patients’ and ‘possibilities to improve treatment adherence’ (Textbox 5, quote 23).

Self-monitoring, combination of home and hospital measurements in the MD (patient and HCP generated)

Patients valued the quick access to their laboratory test results and health information before a clinic visit, enabled by the MD components ‘self-monitoring, combination of home and hospital measurements in the MD’ (Textbox 5, quote 24). Also, patients frequently mentioned that HCPs’ access to their self-monitored health indicators made them feel being ‘looked after’, and that they appreciated the possibility provided by MD to get in touch with HCPs if their health parameters were deteriorating (Textbox 5, quote 25).

HCPs also cited possible benefits of the ‘self-monitoring’ and ‘combination of home and hospital measurements in the MD’ components of the MD (8/10, 80%), as they may help them to track patients’ home measurements (Textbox 5, quote 26). Also, HCPs stated that they may be able to provide a better quality of care and guidance during clinical appointments when they could review the patients' data collected before their clinic visit (Textbox 5, quote 27).

Anticipated barriers of MD use

Clinical compatibility and time constraints (HCP generated)

HCPs frequently cited barriers related to the compatibility of MD with their clinical work and time constraints (4/10, 40%). HCPs mentioned that the use of MD would lead to additional workload (e.g. reviewing patients' electronic health records continuously) and that it would be difficult to incorporate the intervention into their current work schedule (Textbox 5, quote 28).

Technical issues (HCP generated)

HCPs frequently named barriers related to the availability and use of technology necessary to implement MD (4/10, 40%). Specifically, HCPs named a lack of computers, measurement devices, and wireless internet connection at home (Textbox 5, quote 29). Another perceived barrier was the amount of technological connections to different platforms necessary for the implementation of MD (e.g. patient home measurements, laboratory tests) (Textbox 5, quote 30).

eHealth literacy (HCP generated)

HCPs frequently mentioned that patients' eHealth literacy might be a barrier to the implementation of MD in China (6/10, 60%) (Textbox 5, quotes 31).

Other barriers related to features of MD (patient and HCP generated)

HCPs frequently voiced concerns on the potential validity of the electronic data submitted by patients in MD (6/10, 60%); for instance, they named 'invalid measurements on health indicators' (Textbox 5, quote 32). Additionally, patients and HCPs frequently mentioned that the computer-based version of MD was difficult to use; for instance, the need to login to the MD via a separate website (Textbox 5, quote 33). HCPs also cited that the information support website may not provide the personalized and tailored knowledge as desired by patients and HCPs (Textbox 5, quote 34).

Suggestions for adaption and implementation of MD based self-management intervention in China

Recommendation on design and intervention content (patient and HCP generated)

Patients and HCPs mentioned potential improvements for both the design and intervention content of MD (detailed in Textbox 6). Also, more than half of HCPs recommended design adaptations to be made to MD to ensure that the intervention is easy to use by patients, fits well with and supports their clinical workflows (Textbox 5, quote 35).

Implementation strategies: instruction and educational meetings (HCP generated)

HCPs frequently named the necessity to educate patients on the correct use and potential benefits of MD (4/10, 40%). In particular, HCPs mentioned the importance to clearly instruct patients on how to correctly measure health-related indicators and upload their health measurements at home (Textbox 5, quote 36).

Textbox 5. Illustrative quotations for theme 3: adaptation and implementation of the Dutch MD intervention in China.

Online information support

- **Quote 21**: It will be great if I know the meaning of each test indicator online. (Patient 14, female, 52y, CKD G4; focus group 2)
- **Quote 22**: The health education [in Medical Dashboard] is safe. The doctors have checked the content. Patients can read the information according to their needs. (HCP2, female, 30y)
- **Quote 23**: Patients can check directly online about how to use the medication. This can [help] improve their [treatment] adherence. (HCP1, female, 31y)

Self-monitoring and Combination of home and hospital measurements in the Medical Dashboard

- **Quote 24**: It will be convenient if I can see my laboratory tests directly. [...] Especially when doctors are too busy to provide test results. (Patient 15, female, 41y, CKD G4; focus group 2)
- **Quote 25**: Doctors can know our [disease] status at home. We can communicate with doctors directly online. (Patient 20, female, 43y, CKD G2; focus group 1)
- **Quote 26**: There can be continuous care and follow-up if we can see patients' home measurements. (HCP5, female, 34y)
- **Quote 27**: Doctors can provide specific treatment plans according to patients' status at home, such as some medication use. (HCP2, female, 30y)

Clinical compatibility and time constraints

- **Quote 28**: It will lead to extra work burden and costs a lot of time [...] (HCP6, female, 33y)

Technical issues

- **Quote 29**: It seems difficult for [patients in] rural areas [to use Medical Dashboard]. Many patients do not have devices to measure blood pressure. (HCP1, female, 31y)
- **Quote 30**: It is difficult to connect different databases. (HCP6, female, 33y)

eHealth literacy

- **Quote 31**: Some patients could be unfamiliar with the use [of Medical Dashboard] and this will affect the implementation. (HCP4, female, 35y)

Other perceived barriers related to features of Medical Dashboard

- **Quote 32**: The data may not be correctly uploaded by patients, or some patients may not upload data if the values are abnormal. (HCP2, female, 30y)
- **Quote 33**: I always use the smartphone to get a call or read the news. It is difficult if I need to enter websites. (Patient 12, male, 62y, CKD G3; focus group 2)
- **Quote 34**: The information support provides knowledge [of disease] in general. [...] It can be difficult for patients to decide which knowledge is personalized for them. (HCP8, male, 46y)

Recommendation on design and intervention content

- **Quote 35**: This platform must be simple to use and convenient in practice. (HCP8, male, 46y)

Implementation strategies: Instruction and educational meetings (HCP generated)

- **Quote 36**: It is essential to teach patients to conduct the measurements in a correct way to improve the accuracy of the value they measured. (HCP5, female, 34y)

Textbox 6. A summary of needs towards improvement of Medical Dashboard.

Patient & HCP

- Delivery of MD intervention via smart mobile phone apps
- Providing tailored CKD information support
- Peer support
- A psychological module for patients
- Video or voice call to support interactions between HCPs and patients
- Reminders sent to HCPs when patients-entered data is abnormal

HCP

- The wireless tracker in a mobile application to automatically collect measurements
- A user interface platform in a mobile application to visualize data and to review progress

DISCUSSION

Main findings

We examined the perceptions, attitudes and needs of Chinese patients with CKD and HCPs towards eHealth self-management interventions. Our results showed that both patients and HCPs had experience with and expressed potential benefits for CKD eHealth self-management intervention to '*inform*, *monitor and track*', and those to support '*interaction*' and '*data utilization*' were not frequently mentioned. Barriers towards the CKD eHealth self-management intervention implementation were mentioned in relation to information barriers (i.e. quality and consistency of the disease-related information obtained via eHealth), trustworthiness and safety of eHealth resources, clinical compatibility and complexity of eHealth, time constraints and eHealth literacy. Suggestions were also provided to improve the intervention functionalities and content of MD, mainly related to complexity of the platform and compatibility with HCPs' workflows.

The understanding and potential benefit of eHealth

Our finding that eHealth is solely mentioned to '*inform, monitor and track*' as potentially relevant interventions to support CKD self-management underlines the importance of education on functionalities and possibilities of eHealth before (co)designing and implementing eHealth interventions. A recent article suggested increasing educational activities to improve knowledge of eHealth of HCPs; these activities include eLearning, blended learning, courses, simulation exercises, real-life practice, supervision and reflection, role modeling and community of practice learning [43]. Moreover, patients and HCPs should be made aware of the possible benefits but also pitfalls of eHealth, to promote informed decisions on intervention adoption and ownership [43].

Patients and HCPs expressed that easy access to disease-related information and patients' health parameters measurements via eHealth has great potential to improve CKD self-management and care. This finding is in line with other research on eHealth interventions for people with chronic disease [44, 45]. The Health Belief Model [28] indicates that if people believe that the use of health interventions would lead to their expected positive outcomes (perceived benefits), they are more probable to use interventions. Hence, we suggest using implementation strategies based on persuasive system design (PSD) principles [46] and persuasive technology to persuade/nudge patients and HCPs to adopt eHealth, for instance, personalization and tailoring [47] to these needs and attitudes (e.g. needs towards easy access to information). Also, providing information alone is, however, not sufficient to modify behavior [48]. Thus, we highlight the importance of also improving both patients' motivation and their behavioral skills to facilitate their CKD self-management. As an example of eHealth use, serious gaming is cost-effective, flexible, portable, and could invoke intense and durable interest among patients and HCPs in engaging in regular self-management (implementation) [49].

Barriers related to implementation of eHealth

Barriers named by both patients and HCPs were frequently related to the credibility of information provided via eHealth interventions. Several reasons may explain why barriers related to credibility are so important in China. First, patients with CKD in our study expressed a need for an online information platform established by the government or hospital. However, the eHealth information and platforms used by patients and HCPs are mostly developed by commercial eHealth companies, and could hence be considered less 'credible developers'. Second, there is a lack of uniform quality controls and standards on the accuracy of diverse online information in China. Also, patients with low eHealth literacy could not accurately evaluate the quality of eHealth information resources. Hence, a reliable, trustworthy, and literacy-appropriate information source such as a national and trustworthy health education online platform should be developed, thereby ensuring that trustworthy medical information is available for patients with CKD.

HCPs found it difficult to integrate eHealth interventions into their daily working routines in the past (i.e. lack of compatibility with clinical care, the complexity of eHealth, and time constraints). This finding is corroborated by previous research [50-52], underlining the importance of assessing intervention-workflow compatibility (e.g. staff working patterns, practice management) before and during the development and implementation of eHealth interventions [53]. To increase the clinical compatibility of eHealth interventions, based on a recent meta-analysis [54], we argue that eHealth interventions should partially replace existing care elements, instead of adding elements to care. Also, to ensure that the eHealth application is time-saving, we advise that eHealth functionalities must be simple and easy to use and the navigation in eHealth must be clear.

Furthermore, eHealth could increase health inequalities [55]. For instance, a common assumption in eHealth interventions is that users are a homogenous group with similar (eHealth) skills and knowledge. However, patients' low eHealth literacy [56] is commonly reported as a potential barrier to implementation by HCPs in our study. Previous literature also showed that eHealth can be difficult to use for people with lower education level and low health literacy [57, 58]. To help more patients with CKD benefit from eHealth self-management interventions, we should adapt interventions to the needs of all users including vulnerable groups such as people with lower education level and older age and eHealth illiteracy. Based on principles established by the 'eHealth for All' program (https://www.pharos.nl/over-pharos/programmas-pharos/ehealth4all/), we suggest that end users, including those less digitally skilled, should be involved in the co-design of eHealth from the start. Also, it is important to conduct 'blend care' [59]; combining e-Health with face-to-face support to provide people with personal assistance and coaching on eHealth use. Additionally, previous studies showed that the effectiveness of eHealth interventions among vulnerable groups is influenced by the level of adherence to eHealth use [60]. Based on a recent review [61], we suggest that to increase the adherence of eHealth use among vulnerable groups, eHealth tools should provide multimodal content (such as videos and games) and the possibility for direct communication between patients and HCPs.

MD Specification Development

In general, patients and HCPs indicated that the Dutch MD would be helpful to support CKD self-management, especially the online information support, self-monitoring and the combined home- and hospital health measurements functionalities. Considering the anticipated barriers and needs mentioned by patients and HCPs, we argue that some surface level adaptations [62] of Dutch MD should be made to improve the fit with Chinese settings, such as extending the intervention delivery medium to a mobile phone app. Also, participants expressed a "one-size-fits-all" approach would not resonate with patients; The need to add personalized features was emphasized, such as visual aids, pictograms, and customized videos. Additionally, eHealth needs to be easy to use and well-integrated into HCPs' workflows. To ensure the continued effectiveness of MD, the core self-management intervention components that underly its effectivity, such as the provision of online information support or self-monitoring, should not be changed [62].

Transferability and implications

When comparing the identified (anticipated) barriers to CKD eHealth self-management intervention in our setting with other settings reported in our systematic review [19], mostly, performed in western wettings, findings were similar. For instance, the factors “clinical compatibility and complexity of eHealth” correspond to factors related to ‘Innovation’ (e.g. Interventions are compatible with existing work) in the review. Hence, the approach and findings of our study might be applicable and transferable to other eHealth interventions currently developed in China and other developing countries sharing similar contextual characteristics with Chinese settings. Also, the (anticipated) barriers mentioned by patients and HCPs to eHealth based (self-management) interventions in general and Dutch MD intervention in specific were similar. It underlines the importance of exploring the previous eHealth use experience of end users, which could influence their perceptions, attitudes and needs towards eHealth interventions. Additionally, the likelihood of successful adoption of eHealth intervention is increased as the interventions are perceived useful and fit for purpose by the actual users [63]. Therefore, it is important to involve both patients and HCPs in the co-design of eHealth interventions.

Strengths and Limitations

To our knowledge, this is the first study to explore the perceptions, attitudes and needs of patients with CKD and HCPs towards eHealth self-management interventions in Chinese settings. Our study has several strengths. First, we captured a diverse sample (i.e. CKD stage, gender, age range), which ensures that our findings reflect the view of a wide variety of patients with CKD. Second, to improve the robustness of our research, the data collection process and the (preliminary) analysis were performed by two team members who are most closely involved in the fieldwork (HS, WW) to optimize consistency. Also, the framework approach to data analysis allowed data to be compared through the formulation of narratives (in-depth focus) and within- and cross-case comparisons (comparative focus).

Nevertheless, there are also limitations. First, as our findings were not quantified, the relative importance of our findings remains unknown. Second, the HCPs who provided CKD care in the institution were predominantly female. The HCP group interviewed may not have been representative of all HCPs in Nephrology practice. This selection bias might be caused by the fact that participants who were more positive towards self-management were more likely to participate in our study. However, the number of barriers identified in this study might indicate that this bias has remained limited. Additionally, as is inherent to qualitative study designs, this study was only performed within one Chinese setting; the generalizability of the findings to other different cultural contexts is uncertain.

CONCLUSIONS

The limited knowledge on the functionalities of eHealth underlines the need for educational efforts such as eLearning and real-life eHealth use practice before and during intervention design and implementation. To optimize the implementation of eHealth self-management interventions and tailor the evidence-based Dutch 'MD' eHealth self-management intervention for patients with CKD in China, future intervention developers should consider specific characteristics and needs within Chinese settings. Emphasis should be placed on increasing eHealth literacy and credibility of eHealth (information resource), ensuring eHealth to be easy to use and well-integrated into HCPs' workflows.

Authors' contributions

HS led the conception and design of this study and is the main contributor in writing this manuscript. RK, PB, WW, XS, ZL, EB, XL and NC contributed to the conception and design of the study and editing of this manuscript. All authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

Funding

This study is funded by the China Scholarship Council. This funding body had no role in the study design and will not have any role in the collection, management, analysis and interpretation of data and writing the report after the study has been finished.

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Additional file 1. Interview and focus group discussion characteristics.

	Value
Interviews	
Patient face-to-face interviews	
No. of patients participating/invited	11/15
Reasons for non participation	Lack of time due to patients' extended waiting time for a physician consultation or intravenous infusion or lack of interest in the research presented
Duration of patient interviews, min	
Range	40-111
Mean ± SD	55.5±20.8
Health care professional interviews	
No. of health care professionals interviewed/invited	10/11
Reason for non participation	Lack of time due to work obligations
Duration of interviews with health care professionals, min	
Range	46-136
Mean ± SD	67.3±26.4
Patient focus group discussions	
No. of focus group participants/invitees	9/9
Duration of focus group discussion 1, min	32
Duration of focus group discussion 2, min	62

SD, standard deviation.

Additional file 2. Patients' and health care professionals' needs and reasoning of design features of eHealth interventions.

Feature	Description	Reasoning
Patient and HCP		
Mobile phone apps	Using mobile phone apps as mediums in the interventions	• Easily acceptable • Easily accessible • Convenient
HCP		
Animation or videos	Using animations or videos to facilitate information provision of patients	• Acceptable • Intuitive • Enhance the texts
Reminders	An automated prompt to remind patients to take the medications and attend hospital appointments	• Improve treatment adherence
Wearable tracker	Using a wearable fitness tracker to track changes of health indicators over time	• Useful • Convenience
Psychological module	Establishing psychological module with paying attention to patients' mental health	• Decrease patients' anxiety
Patient		
Link with electronic records	Patients get access to hospital electronic medical records	• Ask for advice on records • Review test results and records • Convenient

HCP: health care professional.

Chapter 7

General discussion

General discussion

In this chapter, the main findings of this thesis are summarized. Also, four main topics are discussed below:

(1) The potential role of electronic health (eHealth) interventions in chronic kidney disease (CKD) self-management in Chinese settings;
(2) The key factors influencing implementation of CKD self-management eHealth interventions;
(3) Implications for the development and implementation of CKD self-management eHealth interventions in practice
(4) Recommendations for future research

Main findings of this thesis

In Chapter 2, we systematically reviewed the existing evidence regarding the implementation and effectiveness of eHealth self-management interventions for patients with CKD. The review indicated that eHealth self-management interventions have the potential to improve the health behaviours and health outcomes of patients with CKD. Also, high feasibility, usability, and acceptability of and satisfaction with eHealth self-management interventions were reported. The determinant *ability of health care professionals (HCPs) to monitor and, if necessary, anticipate on patient measurements online* was most commonly mentioned to influence patients' adherence to interventions. However, data on eHealth self-management interventions for patients with CKD in low- and middle-income countries are still lacking such as in China, which is the largest low-income and middle-income country with a current population of 1.4 billion. In Chapter 3, the extent of the burden of CKD in Chinese settings was demonstrated; a high prevalence of reduced kidney function and kidney function decline in the Chinese primary care population was found and associated risk factors were identified. To reduce the burden of CKD in Chinese settings, we used an Intervention Mapping (IM) approach comprising six steps to guide the development and tailoring of the evidence-based Dutch 'Medical Dashboard' (MD) eHealth self-management intervention for patients with CKD in China.

We also developed an evaluation plan for its implementation process and its effectiveness (Chapter 4). Following step 1 of IM (needs assessment), two qualitative studies were performed (Chapters 5 and 6). The first qualitative study examined the beliefs, perceptions and needs of Chinese patients with CKD and HCPs towards CKD self-management (Chapter 5). Chapter 5 showed that most patients and HCPs solely mentioned medical management of CKD, and self-management was largely unknown or misinterpreted as adherence to medical treatment. A paternalistic patient-HCP relationship was often present. Additionally, the barriers, facilitators and needs towards CKD self-management were frequently related to (lack of) knowledge and environmental context and resources. The second qualitative study examined the perceptions, attitudes and needs of Chinese patients with CKD and HCPs towards eHealth based (self-management) interventions in general and the Dutch MD intervention in specific (Chapter 6). Chapter 6 showed that both patients and HCPs recognized, had experience with and expressed potential benefits for CKD eHealth self-management intervention as a means to 'inform, monitor and track'. eHealth interventions to support 'interaction' and 'data utilization' were not frequently mentioned. Barriers towards the CKD eHealth self-management intervention implementation were mentioned in relation to information barriers (i.e. quality and consistency of the disease-related information obtained via eHealth), trustworthiness and safety of eHealth resources, clinical compatibility and complexity of eHealth, time constraints and eHealth literacy. Suggestions to adaptation and implementation of the Dutch MD intervention in China were mainly related to improving the intervention functionalities and content of MD such as addressing the complexity of the platform and compatibility with HCPs' workflows.

The potential role of eHealth interventions in CKD self-management in Chinese settings

CKD poses a severe health and socioeconomic burden to the Chinese population. The burden of CKD is related to the increased prevalence of non-communicable diseases (NCDs) such as diabetes and hypertension [1-5]; these NCDs lead to a high prevalence of CKD (Chapter 3), a lower life expectancy and high costs of medical care [6-9]. Also, patients report severe physical, psychosocial and lifestyle consequences of CKD (Chapter 5). For instance, the overwhelming fatigue, complex treatment regimens, liquid and diet restrictions constrain patients' lives (Chapter 5). Additionally, there is a lack of a strong primary care system in rural China to provide adequate health care for patients with (early) CKD; most of the high-quality resources in medical care such as human capital and modern diagnostic and therapeutic technologies are concentrated in Chinese hospitals. As there is a lack of gatekeeping roles and mandatory referrals in primary care, patients are able to freely self-refer to higher-level of providers according to ability and willingness to pay. Therefore, people visit the hospital directly if they have complaints or for check-ups, and the care for patients with CKD relies heavily on HCPs who work in the Department of Nephrology (Chapters 5 and 6).

China is implementing major reforms in health care services with a focus on strengthening primary health care. The primary health care reforms, first announced in

2009, aim to deliver chronic disease care through community health services with a referral of complex cases to the tertiary hospital system [10]. To cope with the growing burden of CKD and other NCDs, the chronic illness management approaches in Chinese primary health care include engaging a patient central role in the self-management of their condition [11]. The goal of self-management is to identify strategies to help patients manage their condition(s) while leading active and productive lives. Patients with CKD who adequately perform self-management, such as high adherence to medication, exercise and diet recommendations, have fewer doctor visits and hospitalizations [12-14]. Therefore, interventions supporting CKD self-management have great potential to improve the patients' health outcomes, decrease health care costs and increase patient satisfaction.

eHealth-based interventions are increasingly being developed to support CKD self-management in China. In specific, patients with CKD and HCPs indicated that eHealth technology facilitates remote patient-provider communication and exchange of (health) data. Also, eHealth increases healthcare accessibility and efficiency (for patients in a rural area) (Chapter 6). Policymakers and care experts in China have recently launched the national health strategy 'Healthy China 2030' [15]. This strategy describes eHealth technology as an essential pillar to improve disease self-management as well as the accessibility and cost-effectiveness of care in rural areas. Also, patients and HCPs expressed the need towards CKD self-management for better access to and provision of disease-related knowledge, especially through eHealth mediums (Chapter 5). Thus, there is a high need and significant momentum for the implementation of eHealth-based interventions to support CKD self-management in China.

The key factors influencing implementation of CKD self-management eHealth interventions

Evidence regarding the key factors influencing implementation of CKD self-management eHealth interventions is accumulated from our systematic review (global information in Chapter 2) and two qualitative studies conducted in Chinese settings (Chapters 5 and 6). To this end, key factors found (i.e. barriers and facilitators) influencing implementation of CKD self-management eHealth interventions in Chinese settings are structured and categorized following the five domains of the Consolidated Framework for Implementation Research (CFIR) [16, 17]:

- the intervention characteristics, which are the features of an intervention (e.g. stakeholders' perceptions about the relative advantage of implementing the intervention, complexity).

- the outer setting, which includes the features of the external context or environment (e.g. external policy and incentives).
- the inner setting, which includes features of the implementing organization (e.g. implementation climate).
- the characteristics of the individuals involved in the intervention (e.g. knowledge and beliefs of patients with CKD and HCPs about the intervention).
- the implementation process, which includes strategies or tactics that might influence implementation.

The CFIR provides a pragmatic structure for identifying potential implementation strategies for interventions in health systems at multiple levels [18-22]. Also, it has been successfully used to identify determinants of behaviour change and optimize the design and effectiveness of self-management interventions [23]. Figure 1 presents an overview of the CFIR domains and offers insight into the most essential factors in each domain influencing the implementation of CKD self-management eHealth interventions in Chinese settings. Also, it is important to realize that certain factors can be considered both a facilitator and a barrier. For example, knowledge was frequently mentioned as a factor affecting CKD self-management intervention. When there was a lack of knowledge for patients, knowledge was a barrier to CKD self-management; however, patients' sufficient knowledge can be considered as a facilitator.

When comparing the factors critical to CKD self-management eHealth intervention in Chinese setting with other settings reported in our systematic review (Chapter 2) [24], mostly, performed in western wettings, findings were highly similar. The factor "Knowledge & Beliefs" in the domain "Individuals characteristics" corresponds to factors related to the "Users" (e.g. availability of sufficient skills/knowledge of users) in the review. Also, the factors "Quality and advantage of eHealth intervention" in the domain "Intervention characteristics" and "Compatibility" in the domain "Inner setting" correspond to factors related to 'Innovation' (e.g. Interventions are compatible with existing work) in the review. Additionally, the factor of evidence-based implementation strategy such as 'Instruction and educational meetings' in the domain 'Implementation process' corresponds to factors related to 'Innovation strategies' (e.g. well planned/structured implementation process) in the review. The similarity between these findings suggests that although eHealth is a rapidly changing field, several challenges such as clinical compatibility of implementing eHealth intervention remain constant across different geographic regions and over time.

Domain	Factor	Direction
Intervention	• **Complexity (of eHealth)**[6]	–
	• **Quality and advantage of eHealth intervention**	
	-Trustworthiness and safety of eHealth[6]	–
	-Information barriers of eHealth[6]	–
Outer setting	• **Cultural context**	
	-A paternalistic patient–HCP relationship[5]	+ –
	• **Needs & Resources**	
	-Patients' and HCPs' needs towards CKD self-management eHealth intervention[5,6]	+ –
	-Infrastructure of (primary) health care[5,6]	+ –
Inner setting	• **Compatibility**	
	-Clinical compatibility of eHealth[6]	–
	• **Training and support**	
	-Patients' and HCPs' skills/ knowledge[5,6]	+ –
Individuals	• **Knowledge & Beliefs**	
	-Patients' and HCPs' attitudes and beliefs of CKD self-management eHealth intervention[5,6]	+ –
	-Patients' and HCPs' knowledge of CKD self-management eHealth intervention[5,6]	+ –
	• **Patients' and HCPs' concerns about privacy, security, and liability**[6]	–
Process	• **Planning**[5,6]	+
	• **Engaging**	
	-Instruction and educational meetings[6]	+

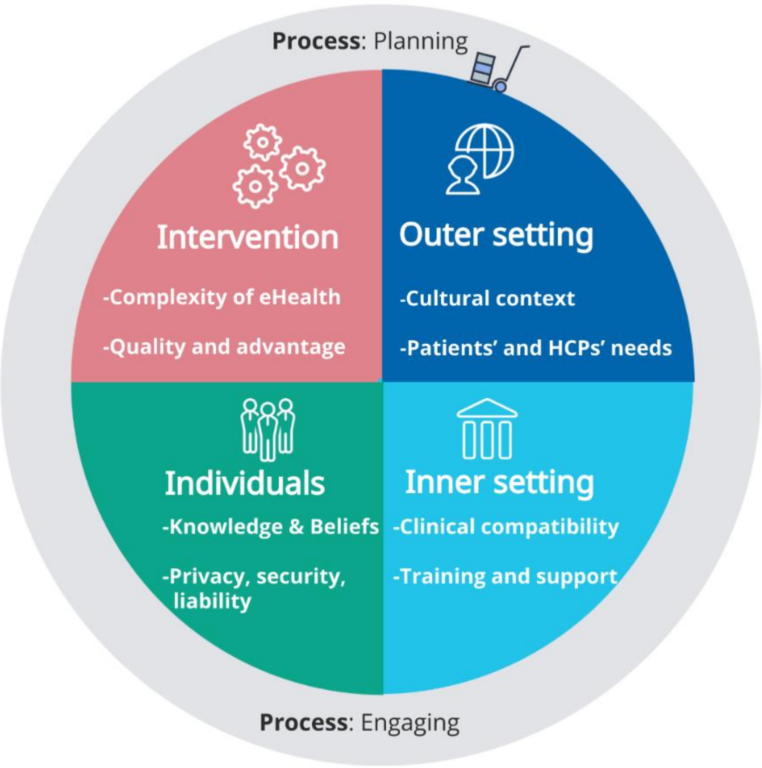


Figure 1. Overview of the different domains of Consolidated Framework for Implementation Research (CFIR) related to CKD self-management eHealth intervention implementation in Chinese settings. [5] chapter 5, [6] chapter 6. +: if the factor is present/considered as a facilitator. -: if the factor is present/considered as a barrier. HCP: Health care professional; CKD: Chronic kidney disease.

However, our findings also indicated that several factors differ from studies conducted in Western settings (Chapter 2) [24], namely ‘Cultural context (i.e. paternalistic patient-HCPs relationship)’ and “Needs and resources” (i.e. patients’ and HCPs’ specific needs in Chinese settings, infrastructure of (primary) health care) in the domain “Outer setting”. For instance, patient autonomy is a core principle of the patient-doctor interaction in western cultures [25, 26]. However, the appreciated paternalistic relationship in our study can be valuable and even essential to improving health outcomes and treatment adherence in some cultural contexts [27, 28]. Under certain conditions, a paternalistic relationship has been shown to provide high-quality health care in some cultural contexts, for instance, if patients prefer and express needs for a paternalistic approach over autonomy [27, 28]. Additionally, there is a high need for an improved infrastructure of primary health care to support CKD self-management in Chinese settings. For instance, patients expressed needs for HCPs’ guidance on daily lifestyle behaviours in primary care (Chapter 5). These identified factors could be leveraged to accelerate the implementation of CKD self-management eHealth interventions in countries sharing similar contextual characteristics with Chinese settings.

All influencing factors in different domains seemed to interact to affect the implementation process and effectiveness of eHealth self-management interventions. For instance, tailoring CKD self-management eHealth interventions to patients’ and HCPs’ attitudes, beliefs and needs can improve the compatibility and solve the concerns, which can therefore increase the perceived quality and advantage of the intervention. Therefore, to increase the success of the implementation of eHealth interventions, the complexities of multiple, interacting domains (e.g. the organization, and the implementation process) need to be addressed [29].

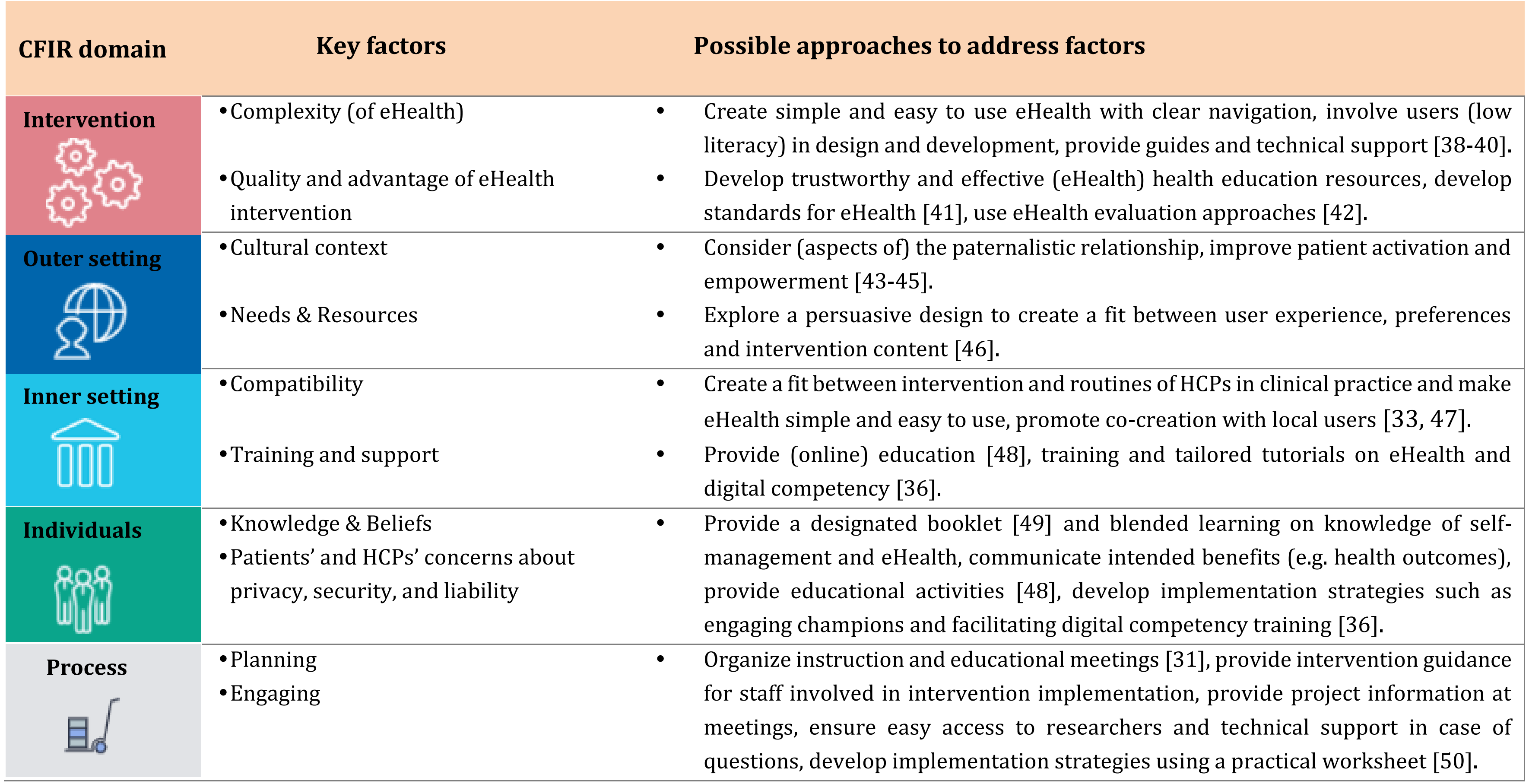
Implications for the development and implementation of CKD self-management eHealth interventions in practice

In this section, several practical implications are provided for future development, adaptation, and implementation of CKD self-management eHealth interventions in Chinese settings and beyond.

Future researchers and eHealth intervention developers should be aware of the identified factors that influence implementation. Also, researchers and eHealth intervention developers need to be aware of local context-specific factors in the settings where CKD self-management eHealth interventions are developed and implemented. For instance, in Chinese settings, when patients prefer a paternalistic approach, the paternalistic guidance on self-management provided by HCPs can help patients become aware of the importance and potential benefits of self-management. As such, an optimal effect of the self-management intervention can be achieved.

Possible approaches are suggested to address the key influencing factors (Figure 2) based on literature specific to eHealth interventions [30] and additional general implementation literature [31]. Essential aspects for these approaches include involving stakeholders (i.e. patients with CKD and HCPs) in the development and implementation process (i.e. a participatory design), adjusting eHealth design features to fit the clinical workflows, and providing the needed support and training. Specifically, developing personalized eHealth instead of applying a one-size-fits-all approach is important to increase the success of the implementation of eHealth intervention [32]. Stakeholder involvement in the development and implementation of eHealth via a co-creation process can achieve this by understanding relevant stakeholders' requirements and needs throughout the process of eHealth development and implementation. As such, interventions can be tailored to these needs and adapted accordingly [33]. Moreover, to improve the adoption of eHealth technologies, education and training are required and should be updated for patients and HCPs to obtain sufficient knowledge of eHealth intervention and digital competency [34] of the most current and useful technologies (e.g. mobile phone applications) in CKD care. For instance, blended learning that combines e-learning and face-to-face methods is suggested to educate HCPs on how to support patient self-management through eHealth [35]. Also, it is vital to include digital competency training of HCPs in the medical curriculum [36]. To this end, the awareness about the importance of educating HCPs and patients on eHealth in medical faculties needs to be raised, which should be backed up by evidence linking the use of eHealth technologies to health, cost, and satisfaction outcomes.

Multilevel intervention components and implementation strategies (e.g. a socio-ecological model-based approach [37]) tailored to all factors related to CFIR domains may be more effective than single-level implementation strategies throughout the development and implementation of CKD self-management eHealth interventions. For instance, eHealth education should be provided for both patients and HCPs in all processes during the development and implementation of eHealth interventions to promote informed decisions on intervention adoption and ownership.



CFIR domain	Key factors	Possible approaches to address factors
Intervention	•Complexity (of eHealth) •Quality and advantage of eHealth intervention	• Create simple and easy to use eHealth with clear navigation, involve users (low literacy) in design and development, provide guides and technical support [38-40]. • Develop trustworthy and effective (eHealth) health education resources, develop standards for eHealth [41], use eHealth evaluation approaches [42].
Outer setting	•Cultural context •Needs & Resources	• Consider (aspects of) the paternalistic relationship, improve patient activation and empowerment [43-45]. • Explore a persuasive design to create a fit between user experience, preferences and intervention content [46].
Inner setting	•Compatibility •Training and support	• Create a fit between intervention and routines of HCPs in clinical practice and make eHealth simple and easy to use, promote co-creation with local users [33, 47]. • Provide (online) education [48], training and tailored tutorials on eHealth and digital competency [36].
Individuals	•Knowledge & Beliefs •Patients' and HCPs' concerns about privacy, security, and liability	• Provide a designated booklet [49] and blended learning on knowledge of self-management and eHealth, communicate intended benefits (e.g. health outcomes), provide educational activities [48], develop implementation strategies such as engaging champions and facilitating digital competency training [36].
Process	•Planning •Engaging	• Organize instruction and educational meetings [31], provide intervention guidance for staff involved in intervention implementation, provide project information at meetings, ensure easy access to researchers and technical support in case of questions, develop implementation strategies using a practical worksheet [50].

Figure 2. An overview of suggestions to address influencing factors of CKD self-management eHealth intervention based on the literature of Health self-management interventions and implementation. CFIR: Consolidated Framework for Implementation Research; HCP: Health care professional; CKD: Chronic kidney disease.

Recommendations for future research

Recommendations are provided that are viewed as vital to improve future research on the implementation of CKD self-management eHealth interventions.

The advantages of eHealth interventions in health care of general population have been described [24, 51, 52]. However, it is unknown to what extent these interventions are effective when implemented among vulnerable groups [53, 54]. Future eHealth intervention design should consider vulnerable groups such as people with lower education level and older age and eHealth illiteracy. Many studies have demonstrated that eHealth is effective in improving health care locally, regionally, and worldwide [55]. However, eHealth could increase health inequalities such as the difference in users and nonusers [56]. A common assumption in eHealth intervention is that users are a homogenous group with similar (eHealth) skills and knowledge. However, in reality, people's level of eHealth literacy can be influenced by environmental and societal factors such as different experiences with eHealth tools, patient age, and education level [57, 58]. In our study, difficulties were experienced during eHealth use by some patients with CKD, such as non-traditional eHealth users (Chapter 6). Therefore, future researchers and eHealth intervention developers should engage in co-creation processes with vulnerable groups during eHealth development and implementation, and tailor interventions to the users' level of (eHealth) literacy, thereby reducing health inequalities.

Digital health technologies (e.g. mobile phones) should be stimulated to improve the infrastructure of primary health care in Chinese settings. The three pillars of primary health care are primary care and essential public health functions as the core of integrated health services, multisectoral policy and action, and empowered people and communities (World Health Organization. A vision for primary health care in the 21st century. 2018). Digital health technologies provide great potential in supporting these pillars and improve the accessibility, affordability and quality of health care (World Health Organization. Digital technologies: shaping the future of primary health care). Specifically, with the use of technologies such as for searching medical knowledge resources, enhancing telecommunication between patients and HCPs, and monitoring healthy behaviours, digital health can be the most suitable and wide-scaled delivery medium of timely and accessible primary health care. This could reduce the burden of CKD, particularly in China which has numerous internet and mobile phone users [59]. Furthermore, on the Chinese market, there are more than 2,000 Internet mobile Health applications and 558 million mobile health application users (http://www. Bigdataresearch.cn/). However, few health apps have been successfully implemented in clinical practice. One possible reason is that most digital health developers are companies, which know more about the commercial interest of technologies than about primary health care (e.g. staff working patterns, practice management). Therefore, to make digital health a reality in Chinese primary health care settings, it is critical that the government play key roles in collaborating with related stakeholders such as companies, innovators and scientific institutes to evolve reliable digital health into primary health care.

An eHealth living lab provides an opportunity to research, connect, share and facilitate eHealth interventions for clinical care in low resource settings. eHealth living-labs, for instance, the National eHealth Living Lab in the Netherlands (https://nell.eu/), provides a platform to bring together relevant eHealth stakeholders including HCPs, students, researchers and policymakers, from diverse institutions, organizations and universities. Within the network of the NeLL, our team from the Leiden University Medical Center and The First Affiliated Hospital of Zhengzhou University shared insights and knowledge in the field of eHealth intervention in CKD self-management. From our experience, this collaborative effort can stimulate the development of eHealth intervention at an international level and facilitate the widespread use of evidence-based eHealth to solve health(care) problems experienced by patients and HCPs in China and the Netherlands. Future collaborations on the development, implementation and evaluation of CKD self-management eHealth intervention in Chinese settings based on Dutch Medical Dashboard will continue.

A qualitative approach was used to explore the beliefs, perceptions and needs of patients and HCPs towards CKD self-management eHealth intervention in Chinese settings. However, the relative importance of influencing factors (e.g. eHealth literacy) for CKD self-management and eHealth intervention implementation was not quantified and remains unknown. Therefore, a future research with a quantitative approach could be conducted to explore the importance of the factors identified. Furthermore, involvement of a multi-stakeholder group in the identification of implementation facilitators and barriers can contribute to a tailored CKD self-management eHealth intervention. As most eHealth applications are developed by companies, it is also important to explore the beliefs, perceptions and needs of eHealth developers in companies towards CKD self-management eHealth intervention.

Conclusions

CKD self-management eHealth interventions in Chinese settings are urgent to reduce the burden of CKD. Also, specific characteristics and needs (e.g. facilitators and barriers) in Chinese settings need to be addressed to optimize the implementation of CKD self-management eHealth intervention. Emphasis should be placed on addressing the existing paternalistic patient-HCP relationship, stakeholder involvement in the development and implementation process, adjusting eHealth design features to fit the clinical workflows, and providing the needed support and training. To the best of my knowledge, the studies in this thesis are the first to focus on local contexts for CKD self-management eHealth intervention in Chinese settings. The research approach used and the results of our study can be relevant for other middle-income countries sharing similar context characteristics. This thesis is a vital step towards the design and implementation of a tailored eHealth solution to improve health outcomes of patients with CKD and address the high burden of CKD in China.

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Chapter 8

Summary

Samenvatting

List of publications

Curriculum Vitae

Acknowledgements

Summary

Chronic kidney disease (CKD) poses a major challenge to public health. Patients with CKD often report severe physical, psychosocial, and lifestyle consequences. Also, health-related and societal costs of CKD constitute a substantial economic burden. **Chapter 1**, the introduction, elaborates on the current state of the art evidence regarding disease self-management of patients with CKD and explains the benefits of electronic health (eHealth) interventions to support CKD self-management. However, data on eHealth self-management interventions for patients with CKD in low- and middle-income countries are lacking. China, a middle-income country, is the largest country globally with a current population of 1.4 billion. China accounts for around one fifth of the global burden of CKD. It also faces challenges in access to (CKD) care. Hence, eHealth self-management interventions are a great potential to Chinese populations. An extensively studied CKD self-management eHealth intervention is the Dutch 'Medical Dashboard (MD)'. It has been demonstrated effective in decreasing the burden of CKD. Therefore, the overall aim of this thesis is to inform the adaptation and evaluation of a tailored CKD self-management eHealth intervention in China based on the Dutch MD intervention.

To examine the effectiveness of eHealth interventions for CKD self-management, we first made an overview of the evidence to date. The aim of **Chapter 2** was to systematically review the existing evidence regarding the implementation and effectiveness of eHealth self-management interventions for patients with CKD. A total of 24 articles comprising 23 studies were included in this review. The most frequently reported effect outcome indicators were specific laboratory tests and blood pressure (BP), whereas satisfaction was the most frequently reported process outcome indicator. Beneficial effects were found for proximal outcomes (e.g. BP control and medication adherence), and variable effects – both beneficial and no effect – were found for more distal outcomes (e.g. quality of life). High feasibility, usability, and acceptability of and satisfaction with eHealth self-management interventions were reported. The determinant *ability of health care professionals to monitor and, if necessary, anticipate on patient measurements online* was most commonly cited to influence patients' adherence to interventions. To conclude, it has been demonstrated that eHealth self-management interventions can improve disease self-management. Also, when health outcomes are closely related to the scope and duration of the intervention implemented, they are most likely to be improved. As mentioned above, data on eHealth self-management interventions for patients with CKD in low- and middle-income countries such as China were lacking.

To understand the burden of CKD in Chinese settings, the **Chapter 3** presented a repeated cross-sectional study in a primary health care population in China. Electronic records were included of 18273 adults who underwent routine health check-ups between 2004-2020 in three primary health care centers in Zhengzhou city, Henan Province in China. Follow-up serum creatinine was available for 3314 participants, with a mean follow-up duration of 1.5 years. Results revealed a prevalence of reduced kidney function of 17.9% and a prevalence of kidney function decline of 19.3%. The prevalence of rapid estimated glomerular filtration rate decline was 22.8%. Female sex, older age, hypertension, overweight, obesity, diabetes, left ventricular hypertrophy and dyslipidemia were independent predictors of reduced kidney function. Moreover, older age and a reduced kidney function at baseline were independent predictors of kidney function decline.

As the burden of CKD is high in China, and eHealth self-management interventions have the potential to improve the health-related quality of life and health outcomes of patients suffering from CKD, CKD intervention could be highly beneficial in China. Therefore, **Chapter 4** used an Intervention Mapping (IM) approach comprising six steps to guide the development and tailoring of an existing evidence-based eHealth self-management intervention for patients with CKD in China – the Dutch 'MD'. We also developed an evaluation plan for its implementation process and its effectiveness. The output of this study will be used to develop a culturally tailored, standardized eHealth self-management intervention that we plan to conduct among patients with CKD in China, which has the potential to optimize patients' self-management skills and improve health status and quality of life. Furthermore, it will inform future research on the tailoring and translation of evidence-based eHealth self-management interventions in various contexts.

Previous literature demonstrates that beliefs, perceptions, and needs of both patients and health care professionals (HCPs) can influence their display of health behaviors and uptake of (self-management) interventions. Therefore, following step 1 of IM - a needs assessment - **Chapter 5** examined the beliefs, perceptions, and needs of Chinese patients with CKD and HCPs towards CKD self-management. A basic interpretive, cross-sectional qualitative study comprising semistructured interviews and observations was conducted in one major tertiary referral hospital in the Henan province in China. A total of 11 adults with a diagnosis of CKD and 10 HCPs who worked in the Department of Nephrology were included in this study. Results showed that most patients and HCPs solely mentioned medical management of CKD; self-management was largely unknown or misinterpreted as adherence to medical treatment. A paternalistic patient-HCP relationship was often present. Finally, the barriers, facilitators and needs towards CKD self-management were frequently related to (lack of) knowledge and environmental context and resources. Future researchers and intervention developers should consider the specific characteristics and needs reported within the Chinese context to guide the development or tailoring of CKD self-management interventions.

Chapter 6 examined the perceptions, attitudes, and needs of Chinese patients with CKD and HCPs towards eHealth based (self-management) interventions in general and the Dutch MD intervention in specific. A basic interpretive, cross-sectional qualitative study was conducted comprising semi-structured interviews with 11 patients with CKD and 10 HCPs, and two focus group discussions with nine patients with CKD. Results showed that both patients and HCPs recognized, had experience with and expressed potential benefits of CKD eHealth self-management interventions as a means to 'inform, monitor and track'. eHealth interventions to support 'interaction' and 'data utilization' were not frequently mentioned. Factors reported to influence the implementation of CKD eHealth self-management interventions included information barriers (i.e. quality and consistency of the disease-related information obtained via eHealth), perceived trustworthiness and safety of eHealth sources, clinical compatibility and complexity of eHealth, time constraints, and eHealth literacy. Also, suggestions regarding the adaptation and implementation of the Dutch MD intervention in China were mainly related to improving the intervention functionalities and content of MD such as addressing the complexity of the platform and compatibility with HCPs' workflows. Future research needs to increase eHealth literacy and credibility of eHealth (as information resource) among patients and health care professionals, ensure eHealth to be easy to use and well-integrated into HCPs' workflows.

In the general discussion, **Chapter 7**, the main findings of this thesis are presented. It also provides a further explanation for the potential role of eHealth interventions in CKD self-management in Chinese settings. Furthermore, the key factors influencing implementation of CKD self-management eHealth interventions are consolidated from each of the studies in this thesis; key factors found (i.e. barriers and facilitators) influencing implementation of CKD self-management eHealth interventions in Chinese settings are structured and categorized following the five domains of the Consolidated Framework for Implementation Research. In addition, implications are discussed for the development and implementation of CKD self-management eHealth interventions in practice and recommendations are provided for future research. To the best of my knowledge, the studies in this thesis are the first to focus on local contexts for CKD self-management eHealth intervention in Chinese settings. The research approach used and the results of our study can be relevant for other countries sharing similar contextual characteristics. This thesis is a vital step towards the design and implementation of a tailored eHealth solution to improve the health outcomes of patients with CKD and address the high burden of CKD in China.

Samenvatting

Chronische nierschade (CNS) vormt een grote uitdaging voor de volksgezondheid. Patienten met CNS krijgen vaak te maken met ernstige fysieke-, psychosociale- en leefstijl beperkingen. Bovendien vormen de gezondheidsgerelateerde- en maatschappelijke kosten van CNS een aanzienlijke economische last. In **hoofdstuk 1** van dit proefschift wordt ingegaan op de huidige stand van zaken met betrekking tot zelfmanagement van patienten met CNS en wordt het belang benadrukt van elektronische gezondheidsinterventies (eHealth interventies) ter ondersteuning van zelfmanagement van CNS. Er zijn echter nog geen gegevens over eHealth-zelfmanagementinterventies voor patienten met CNS in lage- en middeninkomenslanden. China, een middeninkomensland, is met 1,4 miljard inwoners het grootste land wereldwijd; China neemt tevens een vijfde van de wereldwijde ziektelast door CNS voor zijn rekening. Het land wordt bovendien geconfronteerd met uitdagingen in de toegang tot (CNS) zorg. Daarom zijn eHealth-zelfmanagement interventies potentieel van groot belang voor Chinese populaties. Een uitgebreid bestudeerde CNS eHealth-zelfmanagement interventie is het Nederlandse 'Medical Dashboard (MD)'. Het is een bewezen effectieve interventie voor het verminderen van de ziektelast van CNS. Het algemene doel van dit proefschrift is dan ook om informatie te verzamelen voor de aanpassing en evaluatie van een op maat gemaakte CNS eHealth-zelfmanagement interventie in China, gebaseerd op de Nederlandse MD interventie.

Om de effectiviteit van CNS eHealth-zelfmanagement interventies te onderzoeken, hebben we eerst systematische literatuurstudie uitgevoerd naar al het bewijs tot nu toe. Het doel van **hoofdstuk 2** was om een overzicht te geven van het bestaande bewijs met betrekking tot de implementatie en effectiviteit van eHealth-zelfmanagement interventies voor patienten met CNS. In totaal zijn 24 artikelen (bestaande uit 23 studies) geïncludeerd in deze review. De meest frequent gerapporteerde effect uitkomstmaten waren specifieke laboratoriumtesten en de bloeddruk; de meest frequent gerapporteerde proces uitkomstmaat was tevredenheid. Voordelige effecten werden gevonden voor proximale uitkomsten (bijv. bloeddrukcontrole en medicatietrouw), terwijl wisselende effecten – voordelige effecten en geen effect – werden gevonden voor meer distale uitkomsten (bijv. kwaliteit van leven). Er werd een hoge haalbaarheid, bruikbaarheid en aanvaardbaarheid gerapporteerd van eHealth-zelfmanagement interventies, en een hoge tevredenheid over de interventies. De meest genoemde factor die de therapietrouw van patienten beïnvloedt, was *de mogelijkheid van zorgverleners om online metingen van patiënten te monitoren en zo nodig daarop te anticiperen*. Concluderend is aangetoond dat eHealth-zelfmanagement interventies zelfmanagement verbeteren. Indien de gezondheidsuitkomsten dichter gerelateerd zijn aan de scope en aan de duur van de geïmplementeerde interventie, dan kunnen de interventies deze uitkomsten ook verbeteren. Echter, gegevens over eHealth-zelfmanagement interventies voor patienten met CNS in lage- en middeninkomenslanden zoals China ontbraken.

Om inzicht te krijgen in het voorkomen van CNS in een Chinese context, wordt in **hoofdstuk 3** een herhaald cross-sectioneel onderzoek gepresenteerd in een eerstelijnsgezondheidszorgpopulatie in China. Elektronische dossiers werden geanalyseerd van 18273 volwassenen die een routine gezondheidscontrole ondergingen tussen 2004-2020 in drie eerstelijns gezondheidscentra in de stad Zhengzhou in de provincie Henan in China. Follow-up serum creatinine was beschikbaar van 3314 deelnemers, met een gemiddelde follow-up duur van 1,5 jaar. De prevalentie van een verminderde nierfunctie was 17,9% en van achteruitgang van de nierfunctie 19,3%. De prevalentie van snelle afname van de geschatte glomerulaire filtratiesnelheid 22,8%. Vrouwelijk geslacht, hogere leeftijd, hypertensie, overgewicht, obesitas, diabetes, linkerventrikel hypertrofie en dyslipidemie waren onafhankelijke voorspellers van een verminderde nierfunctie. Bovendien waren hogere leeftijd en een baseline verminderde nierfunctie onafhankelijke voorspellers van een verminderde nierfunctie.

Zeker voor China zou een CNS-interventie zeer nuttig kunnen zijn, gezien de hoge prevalentie van CNS, en gezien de potentie van eHealth-zelfmanagement interventies om de gezondheid gerelateerde kwaliteit van leven en de gezondheidsuitkomsten van patienten met CNS te verbeteren. Daarom werd in **Hoofdstuk 4** een Intervention Mapping (IM) benadering toegepast, bestaande uit zes stappen. Dankzij deze IM-benadering kan de Nederlandse evidence-based 'MD' eHealth-zelfmanagement interventie op maat worden gemaakt voor patienten met CNS in China. Ook ontwikkelden we een plan voor de evaluatie van het implementatieproces en de effectiviteit van de interventie. De resultaten van deze studie zullen in de nabije toekomst worden gebruikt om een cultureel aangepaste, gestandaardiseerde CNS eHealth-zelfmanagement interventie te implementeren in China, om de zelfmanagement vaardigheden van patienten te optimaliseren en de gezondheidsstatus en kwaliteit van leven te verbeteren. Bovendien kunnen de resultaten overig toekomstig onderzoek informeren hoe evidence-based eHealth-zelfmanagement interventies op maat kunnen worden gemaakt voor verschillende contexten.

Eerdere studies toonden aan dat overtuigingen, percepties en behoeften ten aanzien van ziekte (en zelfmanagement daarvan) van zowel patienten als zorgprofessionals van invloed kunnen zijn op gezondheidsgedrag en acceptatie van (zelfmanagement) interventies. Na stap 1 van de IM (inventarisatie van behoeften), werd daarom in **hoofdstuk 5** onderzocht wat de overtuigingen, percepties en behoeften van Chinese patienten met CNS en van zorgverleners waren ten aanzien van zelfmanagement van CNS. Een interpretatieve, cross-sectionele kwalitatieve studie bestaande uit semigestructureerde interviews en observaties werd uitgevoerd in een groot academisch ziekenhuis in de Chinese provincie Henan. In totaal werden 11 volwassenen met een diagnose van CNS en 10 zorgprofessionals die op de afdeling Nefrologie werkten geïncludeerd in deze studie. De meeste patienten en zorgverlener noemden alleen de *medische* behandeling van CNS; *zelfmanagement* was grotendeels onbekend of werd onjuist geïnterpreteerd als het volgen van een medische behandeling. Er was vaak sprake van een paternalistische relatie tussen patient en zorgverlener. Tenslotte bleken de barrieres, bevorderende factoren, en behoeften ten aanzien van zelfmanagement van CNS vaak gerelateerd te zijn aan (gebrek aan) kennis en aan context, en aan beschikbare middelen in de omgeving. Deze specifieke kenmerken en behoeften binnen een Chinese context zouden voor toekomstige onderzoekers en interventie-ontwikkelaars een leidraad moeten zijn voor het ontwikkelen of op maat maken van CNS-zelfmanagementinterventies.

Hoofdstuk 6 onderzocht de percepties, attitudes en behoeften van Chinese patienten met CNS en zorgverleners ten aanzien van eHealth-(zelfmanagement) interventies in het algemeen, en van de Nederlandse MD interventie in het bijzonder. Er werd een interpretatieve, cross-sectionele kwalitatieve studie uitgevoerd bestaande uit semigestructureerde interviews met 11 patienten met CNS en 10 zorgverleners, en twee focusgroep discussies met negen patienten met CNS.

Zowel patienten als zorgverleners' herkenden potentiele voordelen van eHealth-zelfmanagement interventies voor CNS om te 'informeren, monitoren en vervolgen'. Ze beschreven dergelijke interventies en ze hadden er ervaring mee. eHealth-interventies om 'interactie' en 'gegevensgebruik' te ondersteunen werden niet vaak genoemd. Factoren die die de implementatie beïnvloedden van eHealth-zelfzorginterventies in het kader van CNS waren onder andere barrieres tot informatie (d.w.z. twijfels over de kwaliteit en eenduidigheid van de via eHealth verkregen informatie), de beleving van de betrouwbaarheid en veiligheid van eHealth-bronnen, compatibiliteit van eHealth met de kliniek, complexiteit van eHealth, beschikbare tijd, en eHealth-geletterdheid. Verder hadden suggesties voor de aanpassing en implementatie van de Nederlandse MD interventie in China voornamelijk betrekking op het verbeteren van de interventiefunctionaliteiten en de inhoud van MD, zoals het aanpakken van de complexiteit van het platform en de compatibiliteit met de werkwijzen van zorgverleners. Toekomstig onderzoek moet de eHealth-geletterdheid en de geloofwaardigheid van eHealth (als informatiebron) vergroten onder patienten en zorgverleners (right?), ervoor zorgen dat eHealth gemakkelijk te gebruiken is en goed geïntegreerd kan worde in de werkwijzen van zorgverleners.

De algemene discussie wordt in **hoofdstuk 7** weergegeven. Eerst worden de belangrijkste bevindingen van dit proefschrift gepresenteerd. Vervolgens wordt een verdere verklaring gegeven voor de potentiele rol van eHealth interventies bij CNS zelfmanagement in Chinese contexten. Verder worden de belangrijkste factoren die van invloed zijn op de implementatie van CNS eHealth-zelfmanagement interventies verzameld uit studies in dit proefschrift; de belangrijkste factoren (d.w.z. beperkende en bevorderende factoren) die van invloed zijn op de implementatie van CNS eHealth-zelfmanagement interventies in Chinese contexten zijn gestructureerd en gecategoriseerd volgens de vijf domeinen van het Consolidated Framework for Implementation Research. Daarnaast worden de implicaties voor de ontwikkeling en implementatie van CNS eHealth-zelfmanagement interventies in de praktijk besproken en worden aanbevelingen gedaan voor toekomstig onderzoek. Voor zover bij mij bekend, zijn de studies in dit proefschrift de eerste die zich richten op lokale contexten voor CNS eHealth-zelfmanagement interventies in Chinese contexten. De gebruikte onderzoeksaanpak en de resultaten van onze studie kunnen relevant zijn voor andere landen met vergelijkbare contextuele kenmerken. Dit proefschrift is een belangrijke stap in de richting van het ontwerpen en implementeren van op maat gemaakte eHealth-oplossingen, die dienen om de gezondheidsuitkomsten van patienten met CNS te verbeteren en de hoge ziektelast van CNS in China aan te pakken.

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Curriculum vitae

Hongxia Shen was born on the 20th of December 1991 in Yanjin, Henan province, China. In September of 2010, she started her study on nursing science at Huanghe Science and Technology College and received her bachelor's degree in July of 2014. Later on, in September of 2014, she started her master's study on nursing science at Zhengzhou University. Her master thesis was entitled: "The study on the status of social functioning and influencing factors for single-centered patients undergoing peritoneal dialysis in rural area". Under the supervision of Prof. Xiaoping Lou, she obtained her master's degree in July of 2017. During her bachelor and master studies, she obtained a "National scholarship", and awards of "Outstanding Graduate Student of Henan Province", "Outstanding Graduate Student of Zhengzhou University".

In September of 2017, she was awarded financial support from the China Scholarship Council and started her PhD research at the Department of Public Health and Primary Care at the Leiden University Medical Centre, Leiden, The Netherlands. Her research was supervised by Prof. dr. Niels Chavannes, Dr. Paul van der Boog and Dr. Rianne van der Kleij-van der Sluis. During her PhD study, she collaborated with Prof. Xiaoping Lou (The First Affiliated Hospital of Zhengzhou University, Zhengzhou, China) and focused on the research of development, adaptation and evaluation of a tailored chronic kidney disease self-management electronic health intervention in China based on the Dutch Medical Dashboard intervention. The results of her PhD studies are presented in this thesis. In 2019, she obtained the second prize of the 'Henan Medical Science and Technology Award' for her research in chronic kidney disease self-management intervention development and evaluation.

Acknowledgements

I would like to express my gratitude to many people for their support and encouragement during my PhD and writing this thesis.

First and foremost, I would like to express my sincere gratitude to my promotor Niels Chavannes, and co-promotors Rianne van der Kleij and Paul van der Boog. Niels, thanks a lot for giving me the opportunity to perform research in such a fantastic research group in the Netherlands. Many thanks for your time in our first phone call, which is the outset of my PhD study. You stimulated me to obtain a deeper understanding of eHealth intervention and realize the great potential role of eHealth in improving health care. Many thanks for your (timely) support and guidance in my research within these four years. Rianne, thank you so much for always supporting me, not only in research methods, but also in improving my language, dealing with cultural differences, listening to my difficulties encountered in life and always encouraging me. I learned a great deal from you in implementation science, qualitative study and looking at the black box. Paul, I greatly appreciated your positive attitudes and support towards my research within these four years, especially for your expertise in chronic kidney disease care; it has been so useful for me to understand the health care in the Netherlands. I would like to thank all my promotors for being with me in research and life during my PhD study. I always feel that the dark clouds above my head went away after our monthly meetings and weekly meetings; all my research questions were well resolved by receiving your help.

I would like to thank my supervisor Prof. Xiaoping Lou in China, who is like my mentor. Many thanks for your instructions on how to get used to Dutch culture and for helping with applications of projects to support my research in China. Many thanks for your patient guidance and all your support over the years. The ways how you behave during life and work provide good examples for me.

I would like to express my sincere thanks to all colleagues at the PHEG and NeLL. All of you always help and encourage me, which makes me feel at home. Many thanks to my sweet roommates Paulien, Elske, Maaike, Marjolein, and Bianca. I am so happy of working together with you. Thanks for taking care of me when I started my PhD study in the Netherlands. Many thanks to Evelyn, Xiaoyue, Ling Wang, Charlotte, Lisa, Johanna, Wenrui, Zhixun and all PhD students. It is so nice to join the PhD meeting, walk together for lunch, share our struggling, join the escape room and have beautiful research days together. Also, I would like to thank my colleagues Monique, Margot, Arno, Tony, Nic, Nick. You helped me to improve my research and get used to the working environment in PHEG.

I would like to express many thanks to my Chinese colleagues Wenjiao Wang, Jie Chen, Wenting Du, Shuchen Wang, Beibei Zhao, Jingjing Kang, Wenjuan Wang, Xiao Zheng. You gave me a lot of help when I conducted research in China and support me during COVID-19. It is so nice to have such lovely colleagues in China. Also, I would like to thank Sanne Gommers. Thanks for your contribution to my PhD research. It is so nice to work with you when we are in China. I can still remember the happy time we had and the cake we had when we recruited our first participant. In addition, I would like to thank my dear Chinese friends, Nannan, Ying Wang, Enchen, Jing Zhang, Xuequan Zhou, Yiling Li, An Wang, Shengnan, Wensen, Li Jia, Yufeng and all my friends. I enjoyed sharing experiences, drinking, having dinner and playing games together with you. Thank you for your friendship that always helped me to get back to work with full of energy!

Last but not the least, I would like to thank my families for your support. Dear dad and mom, thanks a lot for your warm care within these years. You contribute a lot to me and support me to achieve my goals in each stage of my study. Dear brother, sister in law and my two nephews, thanks for being there with me! Dear my boyfriend, Xinwei, we finished our master's studies and came to the Netherlands together to continue our PhD studies. Thanks for being there with me within these six years. You are my best friend and comrade in the arms. Thank you also for your support and wisdom during my difficult times, and your honest feedback after listening to my long and sometimes crazy talk.

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August 2021